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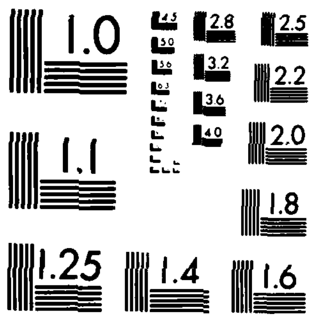

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U.S. Department of Transportation
Federal Aviation Administration

Two-Dimensional Description of Potential Perturbations to the Ozone Layer Due to NO_X and H_2O Aircraft Emissions

Office of Environment and Energy
Washington, D.C. 20591

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16. Abstract

This report is divided into two parts. Part I is an interim report, which describes the basic two-dimensional photochemical model of the atmosphere developed to model the distribution of trace species in the natural atmosphere, as well as potential perturbations arising from NO_x and H_2O emissions from a fleet of supersonic and subsonic aircraft projected to be operational in the 1990-2000 year timeframe. A listing of the model transport parameters is included. Calculations presented in the first part were obtained using reaction rates recommended by the NASA Panel of Data Evaluation in 1979. Preliminary results of the effect on ozone of NO produced by the August 1972 solar proton event are also described. Part II includes an update for the natural and perturbed atmosphere using rates recommended by the panel in 1982. Distributions of trace species calculated for a natural atmosphere are in relatively good agreement with observations. The potential effect of NO_x emissions from the fleet of subsonic and supersonic aircraft examined in this study is to slightly increase the ozone column. The major effect is in the troposphere in the northern hemisphere because of the predominance of low-flying subsonic aircraft in the fleet at this location. The same trends were obtained using either the 1979 or 1982 reaction rates, except that the latest results are slightly lower; a maximum increase in total ozone of approximately 3.1 percent at 30-40°N latitude during October. The corresponding yearly average global increase is approximately 1.5 percent using the 1979 rates and 1.15 percent using the 1982 rates. There are large monthly and latitudinal variations about these averages. Since the amount of H_2O injected into the atmosphere is small

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compared to the natural H_2O levels at the flight altitudes considered, a very minor perturbation of the ozone level was calculated as a result of H_2O aircraft emissions.

TWO-DIMENSIONAL DESCRIPTION OF POTENTIAL PERTURBATIONS TO THE OZONE LAYER DUE TO NO_x AND H_2O AIRCRAFT EMISSIONS

PART I: MODEL DESCRIPTION AND INTERIM MODEL RESULTS USING REACTION RATES RECOMMENDED IN 1979

George F. Widhopf and Leslie Glatt

PART II: MODEL RESULTS USING REACTION RATES RECOMMENDED IN 1982

George F. Widhopf and Edward Ruth

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FIGURES (Concluded)

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PART I

MODEL DESCRIPTION AND INTERIM MODEL R LTS
USING REACTION RATES RECOMMENDED IN 79

1. INTRODUCTION

Our understanding of fundamental aspects of atmospheric chemistry and physics is continually undergoing advancement in many areas which are of basic importance to the evaluation of potential effects of pollutants on the chemical structure of the atmosphere. As such, it is necessary to reevaluate the magnitude of these potential effects whenever significant changes occur in our data base or understanding of pertinent mechanisms.

In this light, we are writing this report to document our latest evaluations of potential perturbations of the ozone layer due to NO_x and H_2O emissions from a projected fleet of subsonic and supersonic aircraft estimated to be operational in the 1990 to 2000 year time frame. The model used in this investigation is a time-dependent, two-dimensional photochemical model of the atmosphere developed in part by funding from the Federal Aviation Administration's High Altitude Pollution Program. This model is undergoing continual revision to include the aforementioned advances and improve the capabilities and realism of the model.

This report is divided into two parts. Part I is an interim report, which describes the basic model and comparisons of predicted distributions of trace species with measurements in the natural atmosphere, as well as an estimate of the effect of aircraft emissions on ozone using reaction rates recommended by the NASA Panel for Data Evaluation in 1979. Preliminary results of the effect on ozone of NO produced by the August 1972 solar proton event are also described.

Part II includes an update of the effect on the ozone layer of the same level and distribution of aircraft emissions of NO_x using an updated list of chemical reactions. Thus, the combined report yields a description of the model and a listing of transport parameters, as well as projections of the effect of ozone emissions on ozone using chemical reaction rates evaluated to be the best available at the time the calculation was performed.

2. MODEL

The model is a time-dependent, phenomenolcgical photochemical model of the atmosphere in which the hydrodynamic variables (mean atmospheric density, temperature, turbulent diffusion coefficients, and mean meridional winds) either are specified, or are obtained indirectly, from observations as a function of time during the year and used to solve the system of species conservation equations for the meridional distribution of trace species throughout the year. The formulation of the model, discussed in Widhopf and Taylor (1974), Widhopf (1975), and Widhopf, et al. (1977) basically is designed to examine relatively small changes in the ozone concentration as a function of the time of year throughout the meridional plane, since any resultant changes in the species concentration occurring as a result of the introduction of a pollutant are not coupled back to the atmospheric dynamics or temperature distributions.

The governing species conservation equation is derived following the general procedure outlined by Reed and German (1965) for representing the turbulent transport flux due to largescale eddies. In the meridional plane, this equation, written in terms of the mass mixing ratio, is of the form

$$
\begin{aligned}
\frac{\partial \rho Y_i}{\partial t} + \frac{\partial \rho w Y_i}{\partial z} + \frac{1}{\cos\phi}\,\frac{\partial \rho v Y_i \cos\phi}{r\,\partial\phi} &= \frac{\partial}{r\,\partial\phi}\left\{\rho k_{\phi z}\frac{\partial Y_i}{\partial z} + \rho k_{\phi\phi}\frac{Y_i}{r\,\partial\phi}\right\} \\
&+ \frac{\rho}{r}\left\{(2k_{zz} - k_{\phi z}\tan\phi)\frac{\partial Y_i}{\partial z} + (2k_{z\phi} - k_{\phi\phi}\tan\phi)\frac{\partial Y_i}{r\,\partial\phi}\right\} \\
&+ \frac{\partial}{\partial z}\left\{\rho k_{zz}\frac{\partial Y_i}{\partial z} + \rho k_{\phi z}\frac{\partial Y_i}{r\,\partial\phi}\right\} + \omega_i + S_i, \quad i=1,2\ldots \qquad (1)
\end{aligned}
$$

where Y_i is the mass mixing ratio, ρ_i/ρ of the i^{th} chemical species; ρ is the local mean atmospheric density; t is the temporal variable; $r = z + R_e$, where R_e is the mean radius of the earth and z is the altitude measured from and normal to the earth's surface; ϕ is the latitude; ω_i is the photochemical rate of production/depletion of the i^{th} species; and S_i is the local source/sink effect. The components of the tensor $k_{\alpha\beta}$ represent the diffusion coefficient in the respective directions arising from largescale eddy motions, whereas v and w are the components of tne mean circulation in the meridional and vertical directions, respectively. This equation is solved for each of the trace species considered.

3. CHEMICAL MODEL

The chemical system considered in this investigation includes the following species: $O(^1D)$, $O(^3P)$, O_2, O_3, N, NO, NO_2, NO_3, N_2, N_2O, N_2O_5, NO_2HO_2, H, OH, HO_2, H_2O, H_2O_2, HNO_3, CO, CO_2, and CH_4. Also included are the important ClO_x species Cl, ClO, $ClONO_2$, and HCl which are produced in the atmosphere as a result of the release at the earth's surface of CF_2Cl_2, $CFCl_3$, CCl_4, and CH_3Cl, among others. Smog-type reactions initiated by the oxidation of methane by OH, which have been shown to be potentially important in the lower regions of the atmosphere, particularly for the evaluation of aircraft emissions effects through the work of Hidalgo and Crutzen (1977), Widhopf, et al. (1977), and Widhopf and Glatt (1978, 1979a,b) are also included. These reactions involve the species CH_3, CHO, CH_2O, CH_3O, CH_3O_2, and CH_3O_2H. The specific reaction system and the associated reaction rate coefficients used in this investigation are tabulated in Table I. These rates follow those recommended by the NASA Panel for Data Evaluation (NASA, (1979)) and subsequent modifications (Smith (1979)).

Computation of solar radiation absorption is an integral step in determining the chemical structure of the atmosphere, since many of the important reactions in the atmosphere are photochemical processes. The diurnally averaged local photolysis rates J_i are calculated at every location in the atmosphere at every third time step by a technique developed by Kramer and Widhopf (1978), using the solar flux data compiled by Ackerman (1971) and updated by Simon (1975). The time variation of the solar zenith angle with latitude and solar declination is included in determining the photolysis rates J_i. The absorption cross sections utilized to compute J_i for the various species are outlined in Widhopf (1975) and updated to those reported in the NASA Data Evaluation (1979). Computation of the $O(^1D)$ photodissociation rate is performed using an appropriately fine resolution (Moortgaat and Kudszus (1978)).

In order to properly model the chemistry of the species N_2O_5, NO_3, and $ClONO_2$ which have important nighttime chemistry, a diurnal averaging was introduced similar to that of Turco and Whitten (1978). Here, the diurnal variation of the concentration is modeled as a constant daytime level followed by constant nighttime level. The ratio between these two states can be calculated using a simplified chemical system and is used to average the chemical production/depletion terms to account for the effect of daytime-nighttime chemistry. This change allows for an appropriate modeling of the nighttime chemistry for NO_3, N_2O_5, and $ClONO_2$ while improving the calculated relative concentrations of NO_2 to NO, among others.

The effect of multiple scattering was also found to have a significant effect on distributions of NO and NO_2 as well as other species. Therefore, it is included in the model using the work of Luther, et al. (1978).

Table I. Chemical Reactions and Rate Coefficients

REACTION	RATE CONSTANT *	REACTION	RATE CONSTANT *
1. $O(^3P) + O_3 \rightarrow 2O_2$	$1.5\times10^{-11} e^{-2218/T}$	29. $N + NO_2 \rightarrow NO + NO$	0.
2. $O_2 + h\nu \rightarrow 2O(^3P)$	J_2	30. $N_2 + O(^1D) \xrightarrow{M} N_2O$	$3.5\times10^{-37}(300/T)^{0.4[illegible]}$
3. $O_3 + h\nu \rightarrow O_2 + O(^3P)$	J_3	31. $NO_2 + N \rightarrow N_2O + O(^3P)$	$2.1\times10^{-11} e^{-800/T}$
4. $NO_2 + h\nu \rightarrow NO + O(^3P)$	J_4	32. $O(^1D) + H_2O \rightarrow 2OH$	$2.[illegible]\times10^{-10}$
5. $O(^3P) + O_2 \xrightarrow{M} O_3$	$6.2\times10^{-34}(300/T)^{2.1}$	33. $O(^1D) + CH_4 \rightarrow OH + CH_3$	1.3×10^{-10}
6. $O(^3P) + NO_2 \rightarrow O_2 + NO$	9.3×10^{-12}	34. $OH + O(^3P) \rightarrow O_2 + H$	4×10^{-11}
7. $O_3 + NO \rightarrow O_2 + NO_2$	$2.3\times10^{-12} e^{-1450/T}$	35. $H + O_2 \xrightarrow{M} HO_2$	$[illegible]\times10^{-32}(300/T)^{1.4}$
8. $O_3 + NO_2 \rightarrow O_2 + NO_3$	$1.2\times10^{-13} e^{-2450/T}$	36. $H + O_3 \rightarrow OH + O_2$	$1.4\times10^{-10} e^{-470/T}$
9. $O_3 + OH \rightarrow O_2 + HO_2$	$1.[illegible]\times10^{-12} e^{-940/T}$	37. $NO + O(^3P) \xrightarrow{M} NO_2$	$k_0 = 1.[illegible]\times10^{-31}(300/T)^{1.8}$, $k_\infty = [illegible]\times10^{-11}(300/T)^{[illegible]}$
10. $NO + HO_2 \rightarrow OH + NO_2$	$4.3\times10^{-12} e^{200/T}$	38. $2OH \rightarrow H_2O + O(^3P)$	$1\times10^{-11} e^{-500/T}$
11. ······	0.	39. $N + O_3 \rightarrow NO + O_2$	0.
12. $OH + NO_2 \xrightarrow{M} HNO_3$	$k_0 = 2.[illegible]\times10^{-30}(300/T)^{2.9}$, $k_\infty = 2.4\times10^{-11}(300/T)^{1.[illegible]}$	40. $HO_2 + h\nu \rightarrow OH + O(^3P)$	J_{40}
13. $HNO_3 + h\nu \rightarrow OH + NO_2$	J_{13}	41. $OH + H_2 \rightarrow H_2O + H$	$2.4\times10^{-12} e^{-1710/T}$
14. $HO_2 + O_3 \rightarrow OH + O_2 + O_2$	$1.1\times10^{-14} e^{-[illegible]/T}$	42. $OH + OH \xrightarrow{M} H_2O_2$	$k_0 = 2.5\times10^{-31}(300/T)^{0.8}$, $k_\infty = [illegible]\times10^{-11}$ [illegible]
15. $HO_2 + O(^3P) \rightarrow OH + O_2$	3.5×10^{-11}	43. $H_2O_2 + O(^3P) \rightarrow OH + HO_2$	$2.8\times10^{-12} e^{-2125/T}$
16. $OH + HO_2 \rightarrow H_2O + O_2$	4×10^{-11}	44. $CO + OH \rightarrow H + CO_2$	$1.[illegible]\times10^{-13}(1 + P_{atm})$
17. $OH + HNO_3 \rightarrow H_2O + NO_3$	8.5×10^{-14}	45. $CH_2O + h\nu \rightarrow H_2 + CO$	J_{45}
18. $H_2O_2 + h\nu \rightarrow 2OH$	J_{18}	46. $CHO + O_2 \rightarrow CO + HO_2$	5×10^{-12}
19. $H_2O_2 + OH \rightarrow H_2O + HO_2$	$1\times10^{-11} e^{-[illegible]/T}$	47. $NO_3 + NO_2 \xrightarrow{M} N_2O_5$	$k_0 = 1.4\times10^{-30}(300/T)^{[illegible]}$, $k_\infty = [illegible]\times10^{-1[illegible]}(300/T)^{0.7}$
20. $HO_2 + HO_2 \rightarrow H_2O_2 + O_2$	2.5×10^{-12}	48. $N_2O_5 \xrightarrow{M} NO_2 + NO_3$	$k_{47}(T)/\|[illegible]\|$
21. $O_3 + h\nu \rightarrow O_2 + O(^1D)$	J_{21}	49. $NO_3 + h\nu \rightarrow 2/3(NO_2 + O) + 1/3(NO + O_2)$	J_{49}
22. $O(^1D) \xrightarrow{M} O(^3P)$	$2.2\times10^{-11} e^{[illegible]/T}$	50. $N_2O_5 + h\nu \rightarrow NO_2 + NO_3$	J_{50}
23. $N_2O + h\nu \rightarrow N_2 + O(^1D)$	J_{23}	51. $NO_3 + NO \rightarrow 2NO_2$	2×10^{-11}
24. $N_2O + O(^1D) \rightarrow N_2 + O_2$	$4.[illegible]\times10^{-11}$	52. $NO_2 + O(^3P) \xrightarrow{M} NO_3$	$k_0 = 9\times10^{-32}(300/T)^{[illegible]}$, $k_\infty = 2.2\times10^{-11}$
25. $N_2O + O(^1D) \rightarrow 2NO$	$[illegible].2\times10^{-11}$	53. $CO_2 + h\nu \rightarrow CO + O(^3P)$	J_{53}
26. $NO + h\nu \rightarrow N + O(^3P)$	J_{26}	54. $H_2 + O(^1D) \rightarrow OH + H$	9.9×10^{-11}
27. $N + O_2 \rightarrow NO + O(^3P)$	$4.4\times10^{-12} e^{-[illegible]/T}$	55. $O(^1D) + CH_4 \rightarrow CH_2O + H_2$	1.4×10^{-11}
28. $N + NO \rightarrow N_2 + O(^3P)$	$[illegible].4\times10^{-11}$	56. $O(^3P) + CH_4 \rightarrow CH_3 + OH$	$3.5\times10^{-11} e^{-4450/T}$

* Units in sec^{-1}, $cm^3\,sec^{-1}$ and $cm^6\,sec^{-1}$ for unimolecular, bimolecular and termolecular reactions.

+ $\{k_0[M]/(1 + k_0[M]/k_\infty)\}\,0.6^{1/\delta}$

δ $1 + \{\log[k_0[M]/k_\infty]\}^2$

D $2.2\times10^{-27} e^{9700/T}$

E $5.7\times10^{14} e^{-10600/T}$

F [illegible]

Table I. Chemical Reactions and Rate Coefficients (continued)

	REACTION	REACTION RATE[1]		REACTION	REACTION RATE[1,2]
57.	$Cl + O_3 \longrightarrow ClO + O_2$	$2.8\times10^{-11}\, e^{-257/T}$	R_1	$CH_3O_2H + h\nu \longrightarrow CH_3O + OH$	J_{R_1}
58.	$ClO + O(^3P) \longrightarrow Cl + O_2$	$7.7\times10^{-11}\, e^{-130/T}$	R_2	$CH_3O_2 + NO \longrightarrow CH_3O + NO_2$	7×10^{-12}
59.	$ClO + NO \longrightarrow Cl + NO_2$	$7.8\times10^{-12}\, e^{250/T}$	R_3	$CH_3O_2 + HO_2 \longrightarrow CH_3O_2H + O_2$	6×10^{-12}
60.	$CH_4 + Cl \longrightarrow HCl + GH_3$	$9.9\times10^{-12}\, e^{-1359/T}$	R_4	$CH_2O + h\nu \longrightarrow H_2 + CO$	J_{R_4}
61.	$Cl + H_2 \longrightarrow HCl + H$	$3.5\times10^{-11}\, e^{-2290/T}$	R_5	$CH_2O + h\nu \longrightarrow H + CHO$	J_{R_5}
62.	$HO_2 + Cl \longrightarrow HCl + O_2$	4.5×10^{-11}	R_6	$CH_2O + OH \longrightarrow CHO + H_2O$	1×10^{-11}
63.	$OH + HCl \longrightarrow H_2O + Cl$	$2.8\times10^{-12}\, e^{-425/T}$	R_7	$CH_3O_2H + OH \longrightarrow CH_3O_2 + H_2O$	$1\times10^{-11}\, e^{-750/T}$
64.	$HCl + O(^3P) \longrightarrow Cl + OH$	$1.14\times10^{-11}\, e^{-3370/T}$	R_8	$CH_2O + O(^3P) \longrightarrow CHO + OH$	$3.2\times10^{-11}\, e^{-1550/T}$
65.	$Cl + OH \longrightarrow HCl + O(^3P)$	$1\times10^{-11}\, e^{-2970/T}$	R_9	$CH_3 + O_2 \xrightarrow{M} CH_3O_2$	$k_o = 2.2\times10^{-31}\,(300/T)^{2.2},\ k_\infty = 2\times10^{-12}\,(300/T)^{1.7}$
66.	$ClO + h\nu \longrightarrow Cl + O(^3P)$	J_{66}	R_{10}	$CH_3O + O_2 \longrightarrow CH_2O + HO_2$	$5\times10^{-13}\, e^{-2000/T}$
67.	$HCl + h\nu \longrightarrow H + Cl$	J_{67}			
68.	$ClO + NO_2 + N_2 \longrightarrow ClONO_2 + N_2$	$k_o = 1.6\times10^{-31}\,(300/T)^{3.4},\ k_\infty = 1.5\times10^{-11}\,(300/T)^{1.9}$			
69.	$ClONO_2 + h\nu \longrightarrow ClO + NO_2$	J_{69}			
70.	$ClO\,NO_2 + Cl \longrightarrow$ Products	0			
71.	$ClO\,NO_2 + OH \longrightarrow$ Products	0			
72.	$ClONO_2 + O(^3P) \longrightarrow ClO + NO_3$	$3\times10^{-12}\, e^{-808/T}$			
73.	$ClO + ClO \longrightarrow ClO + Cl + O(^3P)$	$2.1\times10^{-12}\, e^{-2200/T}$			
74.	$ClO + ClO \longrightarrow 2Cl + O_2$	$1.5\times10^{-12}\, e^{-1238/T}$			
75.	$HO_2 + NO_2 \xrightarrow{M} HO_2NO_2$	$k_o = 2.1\times10^{-31}\,(300/T)^5,\ k_\infty = 6.5\times10^{-12}\,(300/T)^5$			
76.	$HO_2NO_2 + Cl \longrightarrow HCl + NO_2 + O_2$	0.			
77.	$HO_2NO_2 + O(^3P) \longrightarrow OH + NO_2 + O_2$	1×10^{-15}			
78.	$HO_2NO_2 + OH \longrightarrow H_2O + NO_2 + O_2$	5×10^{-13}			
79.	$HO_2NO_2 + h\nu \longrightarrow HO_2 + NO_2$	J_{79}			
80.	$Cl + H_2O_2 \longrightarrow HCl + HO_2$	$1.1\times10^{-11}\, e^{-980/T}$			

[1] Units in sec^{-1}, cm^3sec^{-1} and cm^6sec^{-1} for unimolecular, bimolecular and trimolecular reactions.

$k = \left[k_o[M]/(1 + k_o[M]/k_\infty)\right](0.6)^{1/\delta}$

$\delta = 1 + \left[\log(k_o[M]/k_\infty)\right]^2$

4. BOUNDARY CONDITIONS

The computational domain considered in this investigation extends from the north to the south pole, with a 10^0 meridional resolution, and from the surface to 50 km, with a vertical resolution of $\Delta z = 2$ km from the surface to 12 km, $\Delta z = 1$ km up to 35 km, and $\Delta z = 2.5$ km up to the upper boundary. At the polar regions, a zero latitudinal flux is assumed.

A fixed ozone concentration ($6(10)^{11}$ mol/cm^3) was imposed at the lower boundary, as interpreted from the meridional distributions compiled by Dutsch (1971) and Hering and Borden (1964-67) (as summarized in the data compilation of Wu (1973)). The concentration of N_2O at the lower boundary is prescribed as an average value (0.31 ppmv) interpreted from the tropospheric measurements of Schutz, et al. (1970) and Goldman, et al. (1973). The latitudinal variation of the mass mixing ratio of CO at the surface was interpreted from the measurements of Seiler (1974). The mass mixing ratio of CH_4 (1.61 ppmv) at the lower boundary was specified from the measurements of Fabian, et al. (1979). Injection of NO and NO_2 resulting from the anthropogenetic activities was specified at the lower boundary as interpreted from the estimates of Robinson and Robbins (1971). The species $O(^3P)$, $O(^1D)$, OH, N, and H were takento be in photochemical equilibrium at the lower boundary because of their relatively short lifetimes, whereas H_2O, HNO_3, NO_2, NO, HO_2, H_2O_2, N_2O_5, NO_3, HO_2NO_2, and ClO_x were removed from the troposphere by simulating atmospheric rainout/washout. The species H_2O, HNO_3, H_2O_2, HO_2, H_2O_5, NO_3, HO_2NO_2, and ClO_x are removed at the average rates defined by Junge (1963), whereas NO_2 and NO were assumed to be removed at one-tenth this rate. The rainout/washout model is discussed in more detail in Section 7.

The species $O(^3P)$, $O(^1D)$, O_3, OH, HO_2, H_2O_2, N, H, Cl, ClO, and $ClONO_2$ were assumed to be in photochemical equilibrium at the upper boundary, whereas the mass mixing ratios of NO_2, N_2O, H_2O, N_2O_5, NO_3, HO_2NO_2, CH_4, CO, and HNO_3 were continued analytically to the upper boundary by a

second-order extrapolation in space and time described by Widhopf (1975) and Widhopf and Taylor (1974). This extrapolation allows the use of centered spatial differencing at this boundary, while also eliminating the necessity of specifying a boundary condition for these species at this location. It is an accurate and stable method of evaluating conditions at computational boundaries (Widhopf and Victoria (1973)) when the physical mechanisms interior to the computational domain govern the boundary value. This is the case for N_2O, NO_2, CH_4, N_2O_5, NO_3, HO_2NO_2, H_2O, and HNO_3, which are being transported up into the higher regions of the stratosphere.

5. TRANSPORT DATA

The meridional distributions of both mean density and temperature were specified using the data obtained from 10 years of observations which were analyzed and compiled by Louis (1973, 1974). These averaged data are specified from the surface to 68 km for the entire meridional plane and for each of the four seasons. A tabulation of the temperature is included in the Appendix.

Luther (1973a,b) has analyzed the heat transfer, temperature, and wind variance data of Oort and Rasmussen (1971), using the procedure outlined by Reed and German (1965) for defining the components of the anisotropic turbulent eddy diffusivity tensor. The three components $k_{\phi\phi}$, $k_{\phi z}$, and k_{zz} are specified for the northern hemisphere from the surface to 60 km. Values for the components of the diffusivity tensor in regions where observational data were not available were obtained by Luther by extrapolation, using the results of Wofsy and McElroy (1973) and Newell, et al. (1966). These coefficients are specified for each month and initially were used to parameterize the components of the turbulent diffusivity tensor. The values for the southern hemisphere were obtained by reflecting the northern hemispheric values, shifted by six months, and applying them appropriately in the southern hemisphere. However, when these transport coefficients were tested against the dispersion of inert tracers in the atmosphere, they were found to be not totally adequate (Widhopf (1975)) and were improved by numerical experimentation described by Widhopf, et al. (1977). Additional tropospheric modifications which were necessary to model the water vapor distributions are discussed in Widhopf and Glatt (1978, 1979a,b). The most current values of the turbulent diffusion coefficients used in the model for the months of October, January, April, and July also are included in the Appendix.

The mean meridional circulation was obtained from the work of Louis, et al. (1974), who calculated the circulation patterns by solving the continuity and energy equations using compiled observations of the local meridional temperature distributions and heat transfer rates. These same data sources were used to define the thermal structure of the atmosphere, previously discussed. The circulation patterns are specified for the entire meridional plane for each season from the surface to 50 km. In order to insure that total mass conservation was satisfied, the vertical wind component obtained by Louis was specified and the meridional component calculated from the global continuity equation. Both the vertical and meridional wind velocities are tabulated in the Appendix.

In order that smooth variations of all these parameters exist throughout the year, the temperature, density, and transport parameters (k_{zz}, $k_{\phi z}$, $k_{\phi\phi}$, and w) were specified at each location by fitting the data previously described using a five-term Fourier series in time.

6. NUMERICAL SCHEME

In this model, an accurate (second-order in space and time) and efficient time-implicit finite difference scheme has been employed to solve the governing individual species conservation equation for those species with chemical lifetimes less than two days ($O(^1D)$, $O(^3P)$, O_3, N, NO, NO_2, NO_3, NO_2HO_2, N_2O_5, H, OH, HO_2, H_2O_2, Cl, ClO and $ClONO_2$). Advective and diffusive terms that are important in determining the time-dependent distributions of the species are treated using a leap-frog and a Dufort-Frankel finite difference scheme, respectively.

The time-implicit method makes use of a second-order accurate method developed by Widhopf and Victoria (1973). In this method, the chemical production/loss term $\mathring{\omega}_i$, at a specific mesh point and at the new time level n+1, is approximated by the expansion

$$\mathring{\omega}_i^{n+1}\,(Y_i,\rho,\cdot) = \mathring{\omega}_i^n + \sum_{i=1}^{N}\left(\frac{\partial\mathring{\omega}_i}{\partial Y_i}\right)^n\left(Y_i^{n+1} - Y_i^n\right) + \left(\frac{\partial\mathring{\omega}_i}{\partial\rho}\right)^n\left(\rho^{n+1} - \rho^n\right)$$

$$+\left(\frac{\partial\mathring{\omega}_i}{\partial T}\right)^n\left(T^{n+1} - T^n\right) \tag{2}$$

where the index i denotes the species i, Y_i the corresponding mass fraction, T the temperature, ρ the density, n the current time level of the computation, and N the number of species considered. All partial derivatives

of $\mathring{\omega}_i$ are analytically computed and evaluated at the current time level n. In addition, $\mathring{\omega}_i^n$ is approximated by the following:

$$\mathring{\omega}_i^n = \frac{\mathring{\omega}_i^{n+1} + \mathring{\omega}_i^{n-1}}{2} .$$

The use of these relations in the governing species conservation equations results in a linear set of coupled equations for Y_i^{n+1}. (For this problem, the time variations of ρ and T are specified.) These equations are coupled only in time and not in space, and thus the technique results in a solution of a set of N_s linear equations at each mesh point. The stability and accuracy of the scheme is discussed by Widhopf and Victoria (1973).

This time-implicit algorithm overcomes the "stiff" nature of the governing equations, which results from the wide range of chemical time scales of the problem. For the current numerical system, the allowable time step is determined by the convective time-step limitation, which yields a maximum time step of a few days. In order to simplify the calculation and reduce the N_s matrix size (with analogous reduction in computation time), only those species whose shortest chemical time scales are less than two days throughout the computational domain need to be solved using the time-implicit algorithm. All other long-lived species (N_2O, H_2O, HNO_3, CO, CH_4, and HCl) are solved in a straightforward explicit manner. This combination of numerical algorithms has proven to be computationally stable and accurate with a significant reduction in computation time. The simulation of one complete yearly cycle requires approximately 25 min on a CDC 7600 and includes all detailed radiative flux calculations.

7. WASHOUT/RAINOUT

A very simple empirical approach, somewhat consistent with this type of empirical photochemical model of the atmosphere, has been used to model rainout/washout because of the limited knowledge of the dominant mechanisms controlling the distribution of water vapor in the stratosphere and troposphere. Other more complicated approaches were attempted; however, each, at some point, required fundamental empirical or assumed information. For example, rainout occurs when warm, moist air ascends and saturates; however, in the present model, the vertical velocities are prescribed in the mean and have no meaning when applied to the determination of a condition when rainout can occur. As a result, we have used the following approach due to its simplicity and ease in interpreting the consequences of specifying empirical information.

Specifically, rainout is treated as a first-order removal mechanism proportional to the local water vapor concentration and removed throughout the troposphere using the average precipitation time-constant interpreted from available data. The latitudinal variation of the local resident time, $a(\phi)$ (1/sec), as interpreted from Junge (1963), is used. The time-dependent surface boundary condition for water vapor is a relative humidity specification using the work of Manabe and Wetherald (1967), while a flux-type boundary condition is used at the upper boundary. A more detailed description of the model is included in Widhopf and Glatt (1979a). Typical model results for various northern latitudes are compared to available data in Section 8 which describes the model results for the natural atmosphere.

8. NATURAL ATMOSPHERE

Using the chemical system and reaction rates listed in Table I, the variation of the chemical structure of the atmosphere was calculated for the entire yearly solar cycle. This simulation was carried out until the ozone column calculated at each latitude differed by no more than 0.1 percent from one year to the next throughout an entire year. Since there is no quantative agreement on how much ClO_x is presently in the atmosphere, and we can only estimate on how much will be present in the future, combined with the fact that the cost of a 20- to 40-year simulation is prohibitive, ClO_x was handled in a parametric manner in this study. Specifically, two calculations were performed in an attempt to somewhat bound the problem: one with 2 ppbv ClO_x in the stratosphere and a calculation with no ClO_x present.

ClO_x (Cl, ClO, $ClONO_2$, and HCl) was held fixed in the stratosphere at altitudes where NO_y (N, NO NO_2, NO_3, HNO_3, N_2O_5, NO_2HO_2) is essentially at a constant mixing ratio. Initially, the concentrations of Cl, ClO, $ClONO_2$, and HCl were computed in equilibrium with 2 ppbv in the stratosphere. Subsequently, at each time step the total ClO_x at the described altitudes was maintained at 2 ppbv by the addition of a source of HCl. Resultant distributions obtained in this manner, properly nondimensionalized, agree with other two-dimensional model simulations reported by Borucki (1979).

Model results for the monthly variation of the total ozone column as a function of latitude are shown in Fig. 1 for the two cases described, together with the data compilation of observed ozone columns (Dutsch (1971)). Since the transport has been developed independent of ozone observations, the ability to predict the spatial and temporal variation of the concentration of ozone is considered a test of the model transport as well as the chemistry. The variation of the ozone column in the northern hemisphere computed with

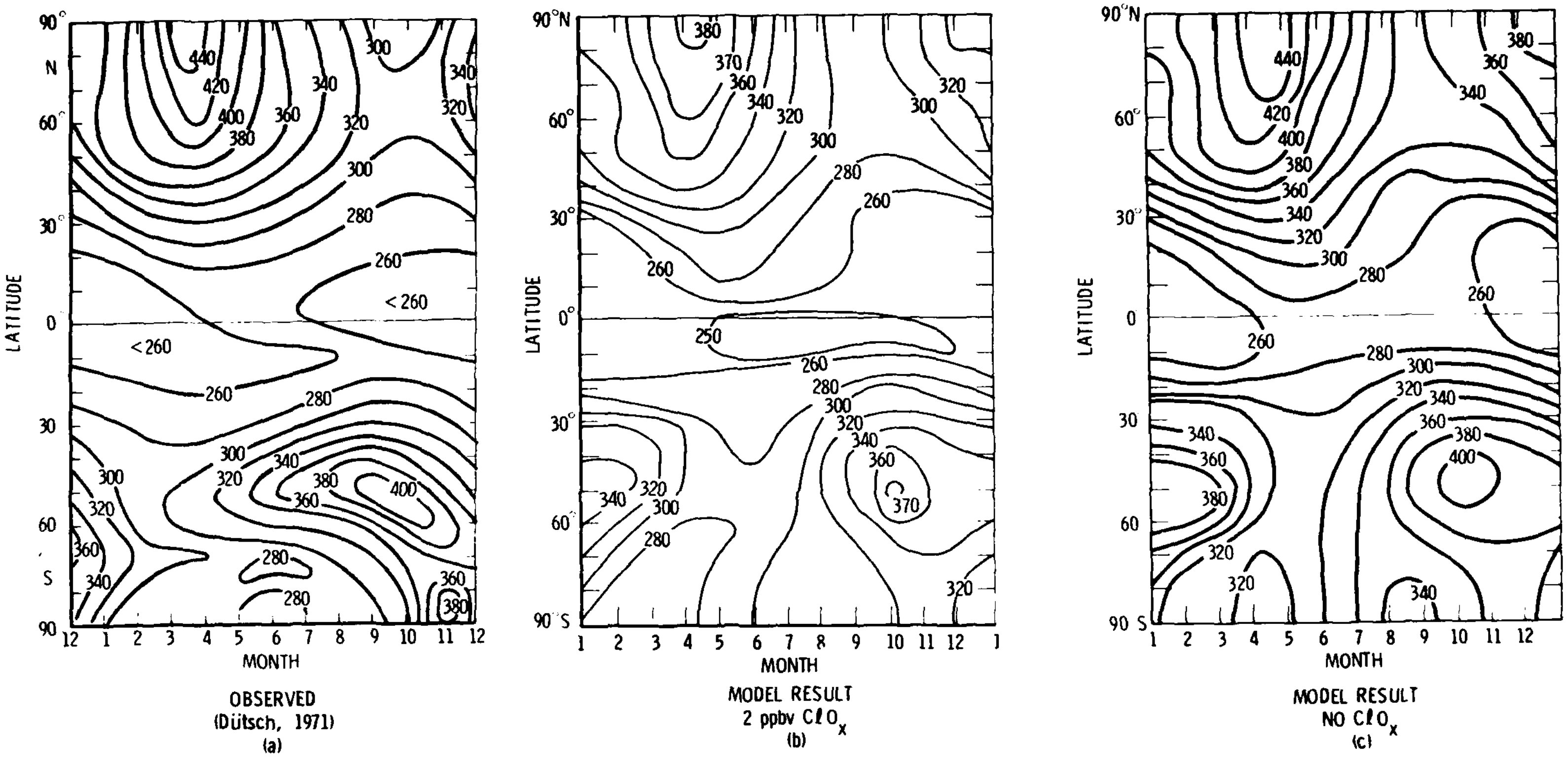


Fig. 1. Calculated and Observed Monthly Variation of the Total Ozone Column as a Function of Latitude (10^{-3} cm at STP)

ClO_x absent is in good agreement with the observations, whereas that obtained with 2 ppbv ClO_x (probably indicative of the ClO_x present in the atmosphere some time in the future) is lower than observations, as would be expected.

Shown in Figs. 2a through 2d is a comparison of the computed ozone profiles for these two cases at various latitudes during the mid-months of the four seasons. Earlier model results (Widhopf, et al. (1977)) obtained using the 1976 chemical system are included for comparison purposes. The transport specifications are the same in all the calculations shown except for some differences in the troposphere. The ozone profiles for the case in which 2 ppbv ClO_x is present in the stratosphere are in agreement with the data except for the peak concentrations, which are low. This accounts for the lower ozone columns shown in Fig. 1b. The calculated tropospheric ozone levels generally are lower than observed levels. For the case in which ClO_x was not considered, the peak values increased, and the ozone profiles are in better agreement with data, except at altitudes higher than approximately 27 km where the ozone concentration is higher than observed. This points to the fact that there is, in fact, some ClO_x presently in the stratosphere and must be considered in order to be able to calculate the correct level of ozone above approximately 30 km. This is more vividly demonstrated in Fig. 3, where the ozone profiles calculated with 2 ppbv ClO_x and without ClO_x present are com- pared with rocket measurements.

As stated, the level of 2 ppbv of ClO_x was chosen in order to provide an initial estimate of the effect of ClO_x. A comparison of the calculated profiles of Cl, ClO, and HCl with corresponding available measurements is shown in Figs. 4a and 4b. Because ClO_x was introduced uniformly throughout the year, the variation of the calculated Cl and ClO concentrations does not vary much (10 percent) with time of year. Also, because we have introduced ClO_x in a parametric manner, at a level estimated to be reasonable, any direct comparisons with ClO_x measurements are not strictly valid, but provide only relative comparisons. However, the profiles at 30^{o}N during

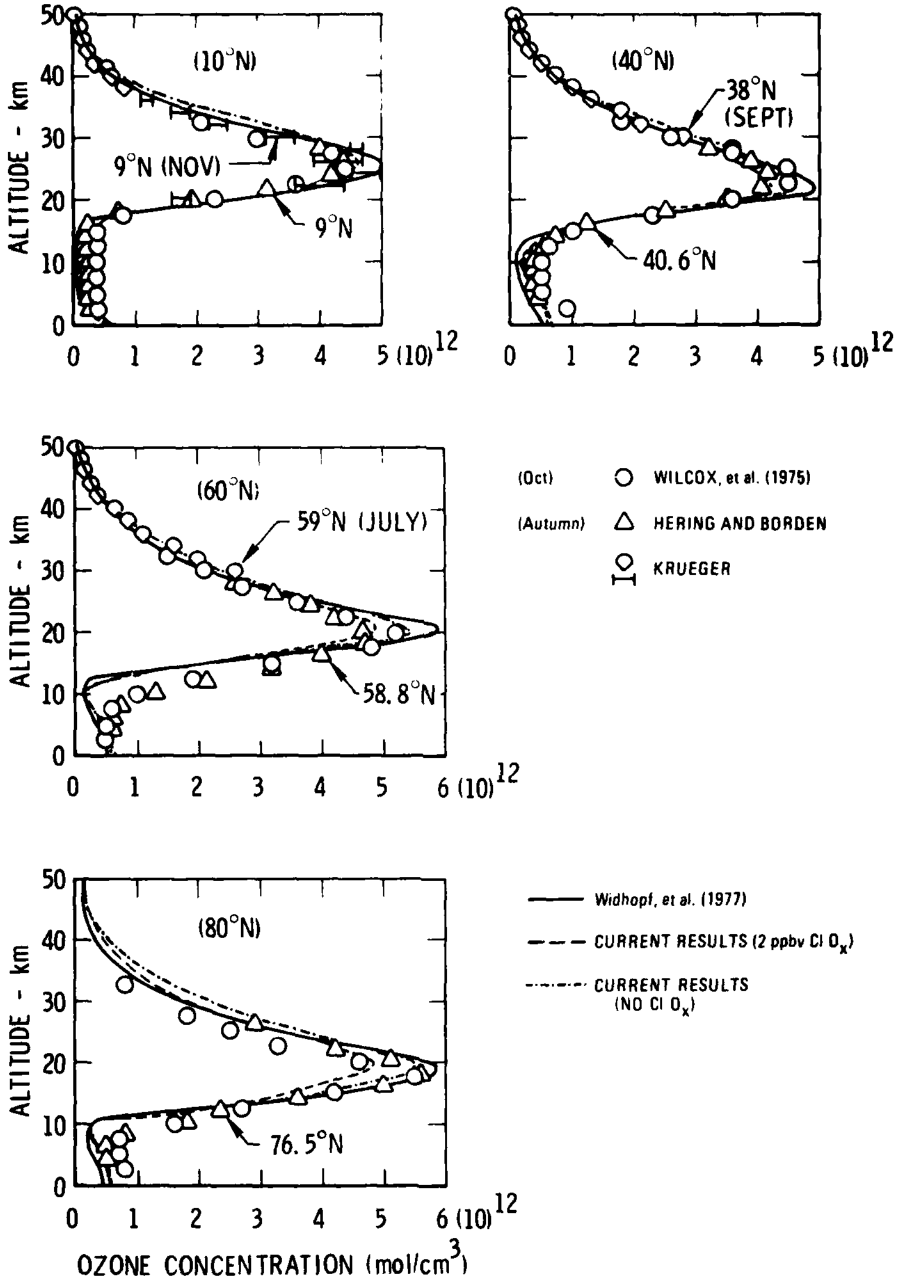


Fig. 2a. Comparison of Calculated and Observed Ozone Profiles during October

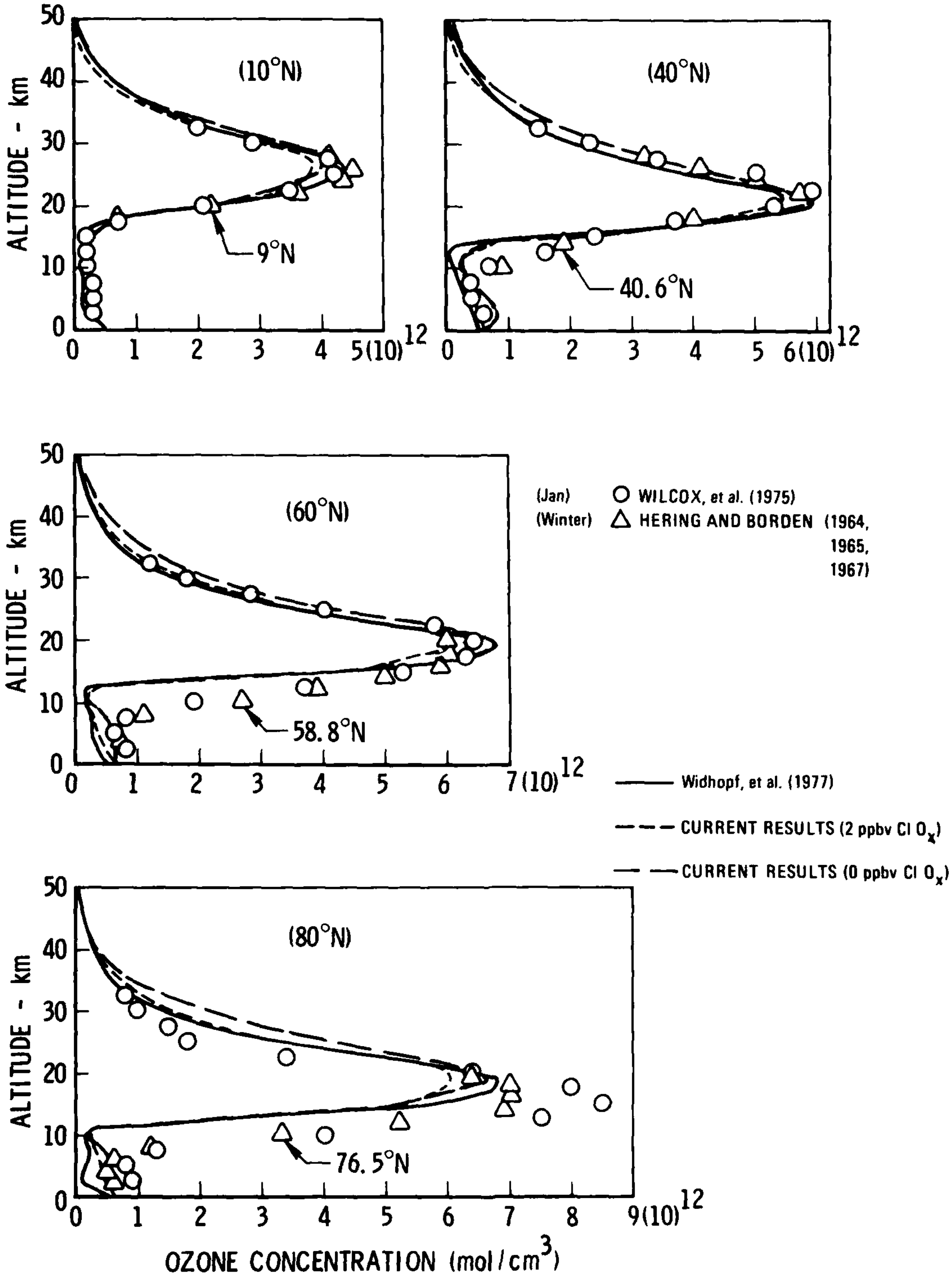


Fig. 2b. Comparison of Calculated and Observed Ozone Profiles during January

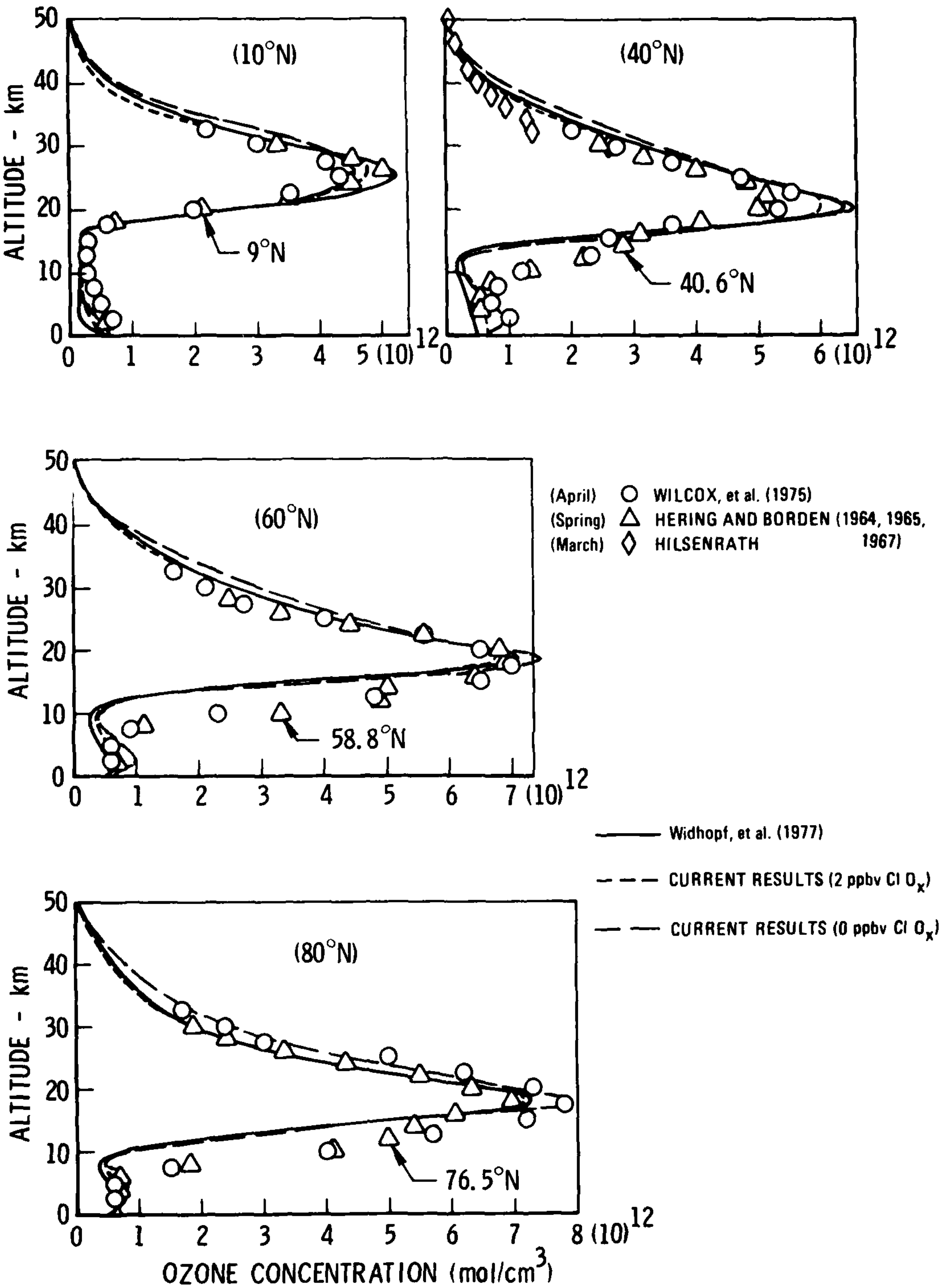


Fig. 2c. Comparison of Calculated and Observed Ozone Profiles during April

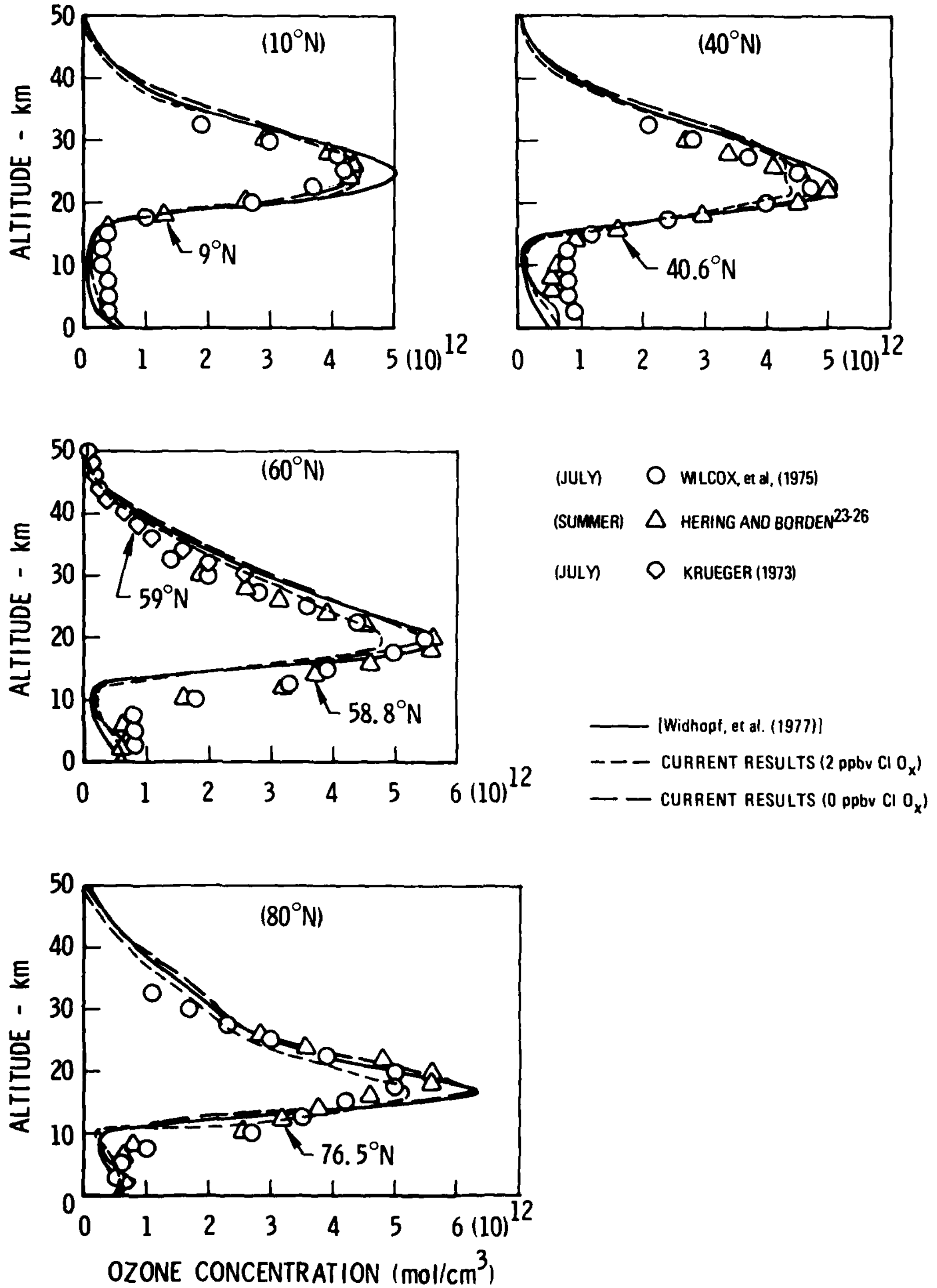


Fig. 2d. Comparison of Calculated and Observed Ozone Profiles during July

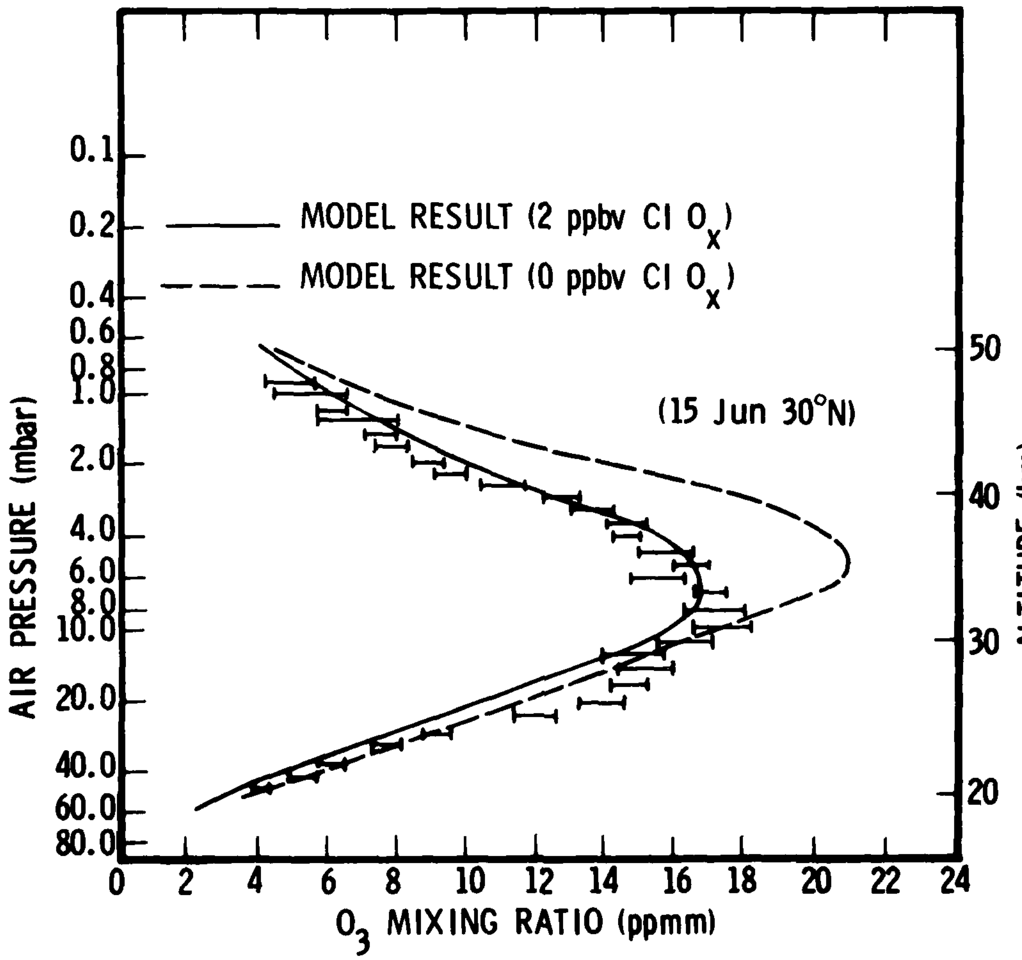


Fig. 3. Comparison of Calculated Ozone Profiles (15 June at 30°N) with Measurements

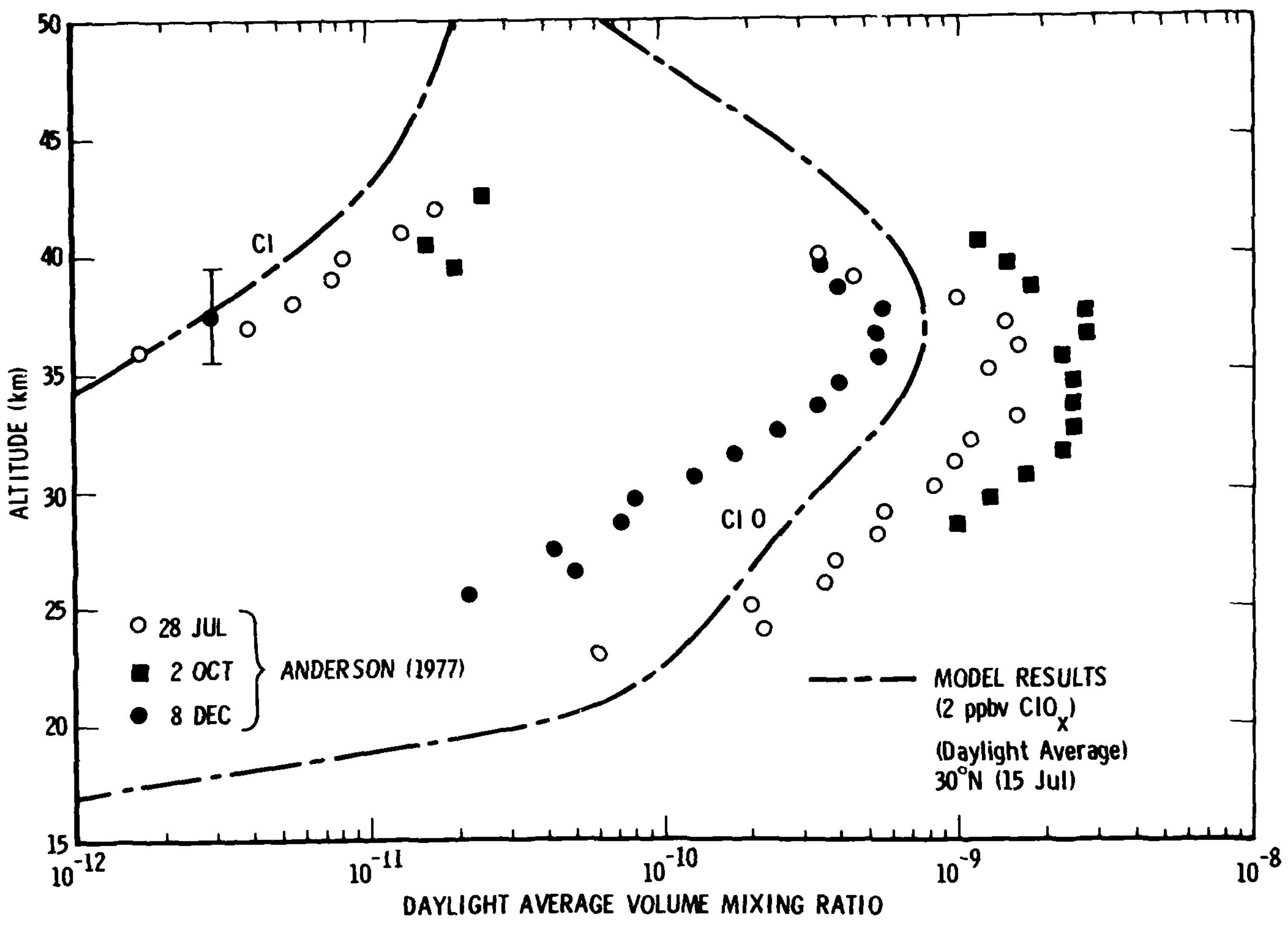


Fig. 4a. Comparison of Calculated and Observed Cl and ClO Profiles

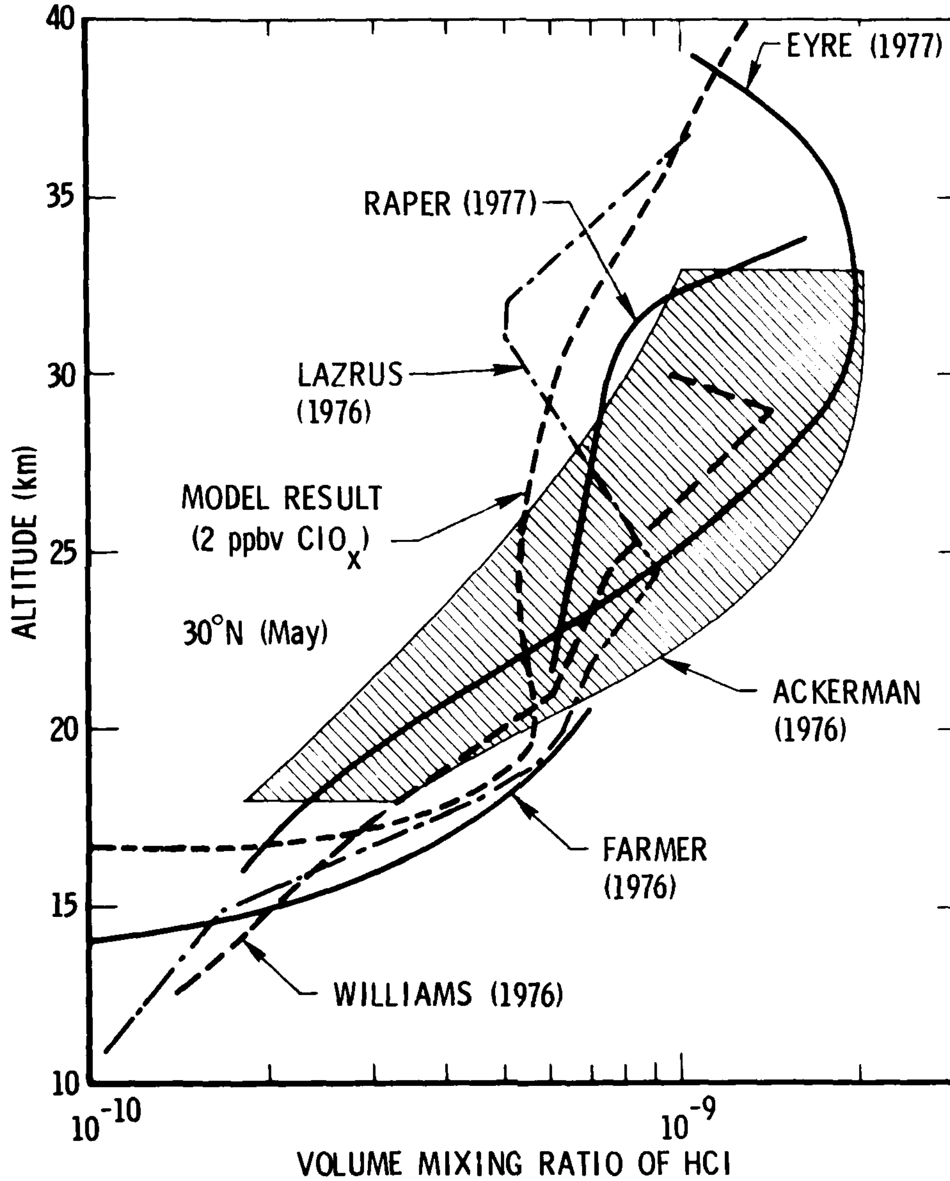


Fig. 4b. Comparison of Calculated and Measured Distribution of HCl

July are in agreement with measurements made during July at $32^{o}N$. The calculated HCl distribution during May is shown in Fig. 4b and is in comparative agreement with available measurements. Further study will determine the relative significance of these ClO_x comparisons.

Other comparisons with data are useful in elucidating areas where model predictions using the presently recommended chemical set are in agreement with observations and where more research is needed. Some tropospheric results are discussed first. All these results are plotted for the case which includes ClO_x, since the introduction of ClO_x does not substantially effect the distribution of these trace species, at least within the accuracy limits of the data.

Shown in Figs. 5a through 5d are some typical H_2O profiles calculated during the mid-months of the four seasons compared to available data. The agreement is good below 10 km, and the calculated level is higher in the stratosphere than the data compiled by Harries (1976). However, more recent measurements in the stratosphere (*Schemeltekopf (1979)) show levels of water* vapor approximating those calculated; in some cases there are measurements of even higher levels.

Tropospheric NO_x profiles are shown in Fig. 6 and compared to tropospheric estimates made by Fishman and Crutzen (1978) in their attempt to balance the CO budget. The rapid increase in the concentration of NO_x in the lower few kilometers is due to the inclusion of anthropogenetic sources of NO_x at the surface. Above 2 km the calculated NO_x profile approximates the levels that were estimated by Fishman and Crutzen. The dramatic reduction in the NO_x level from that calculated using the 1976 chemical system is obtained with the introduction of the larger NO + HO_2 chemical rate used in the present calculations. These comparisons are useful, but measurements of NO_x concentration are needed in order to validate any of the model predictions/estimates.

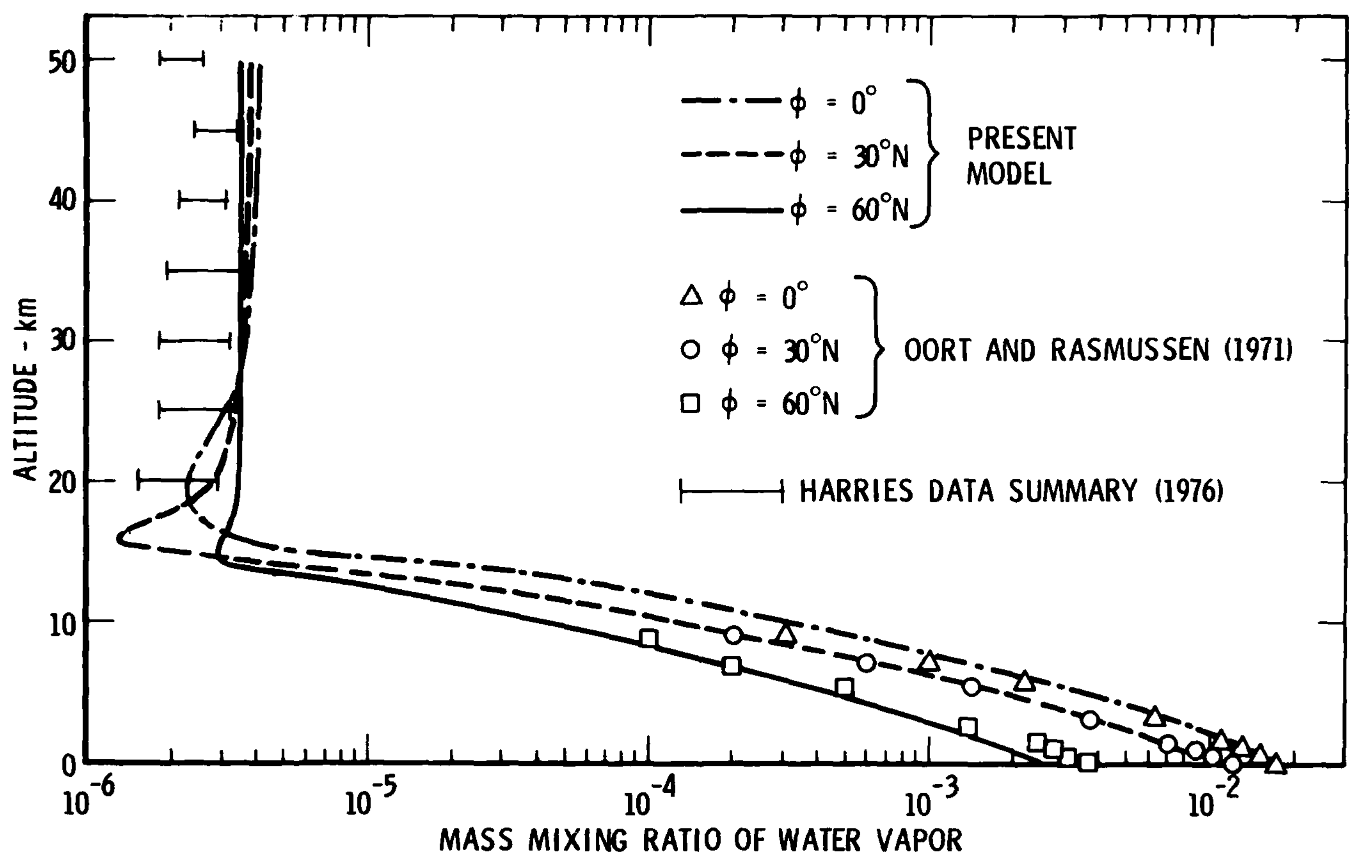


Fig. 5a. Water Vapor Profile in Natural Atmosphere in October

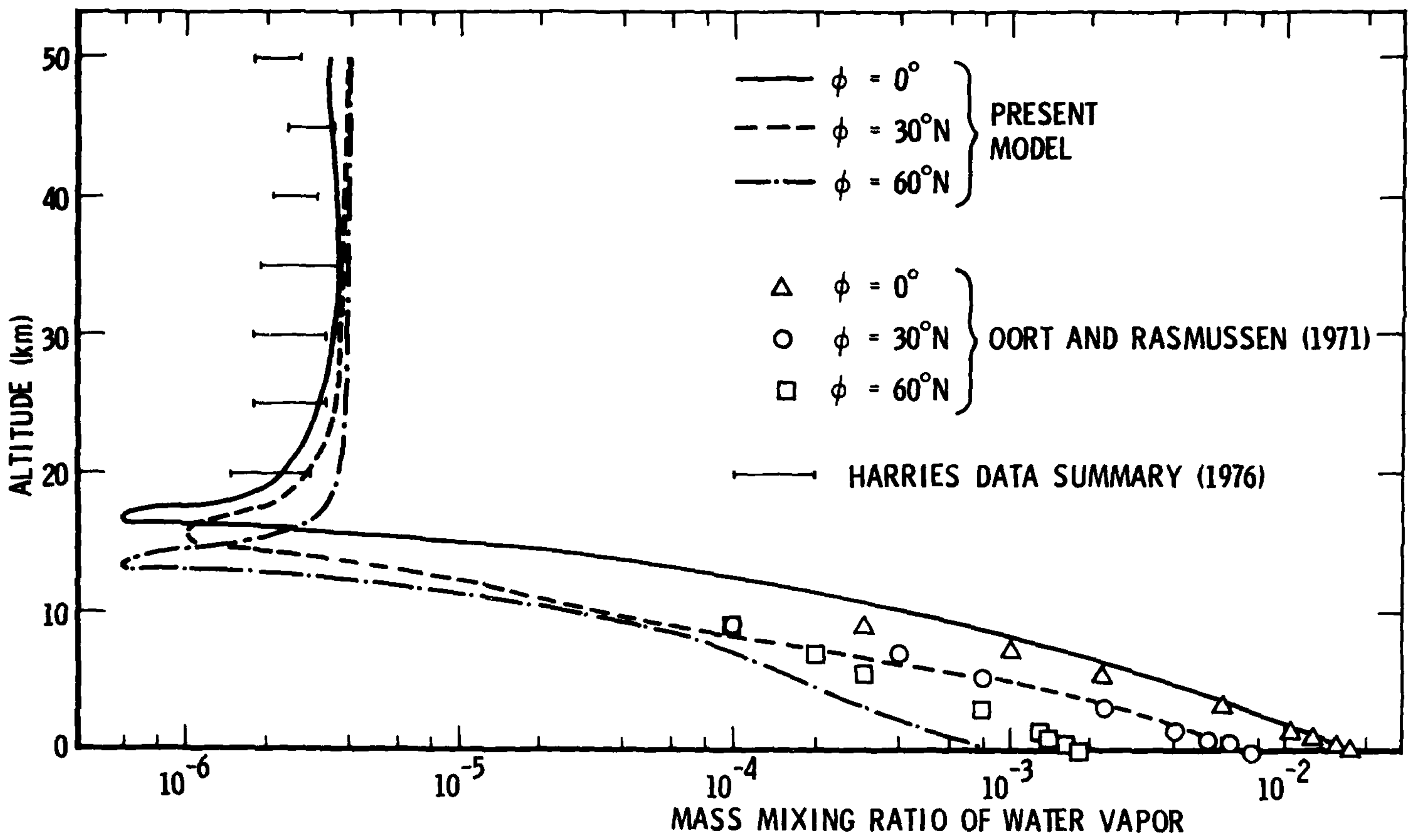


Fig. 5b. Water Vapor Profile in Natural Atmosphere in January

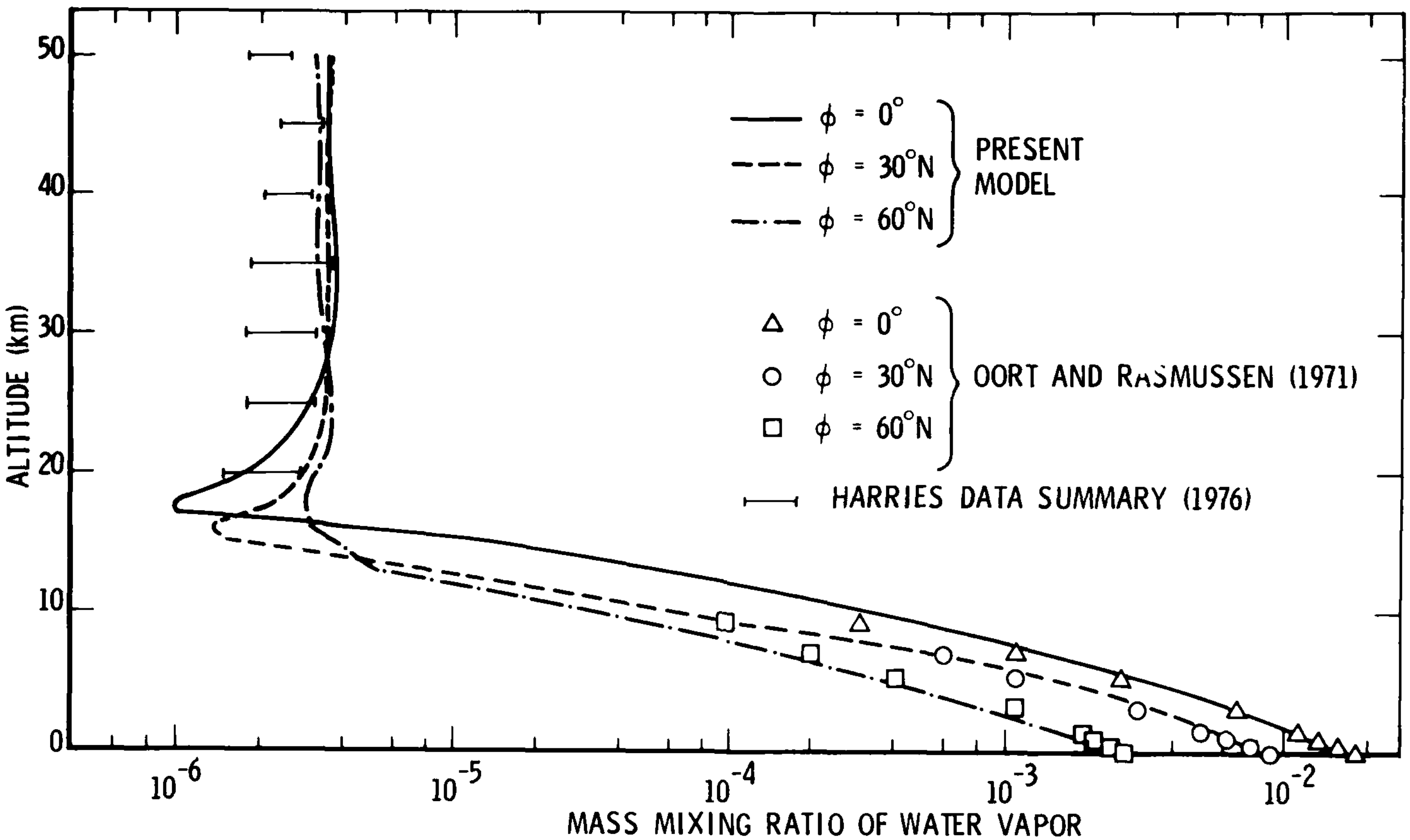


Fig. 5c. Water Vapor Profile in Natural Atmosphere in April

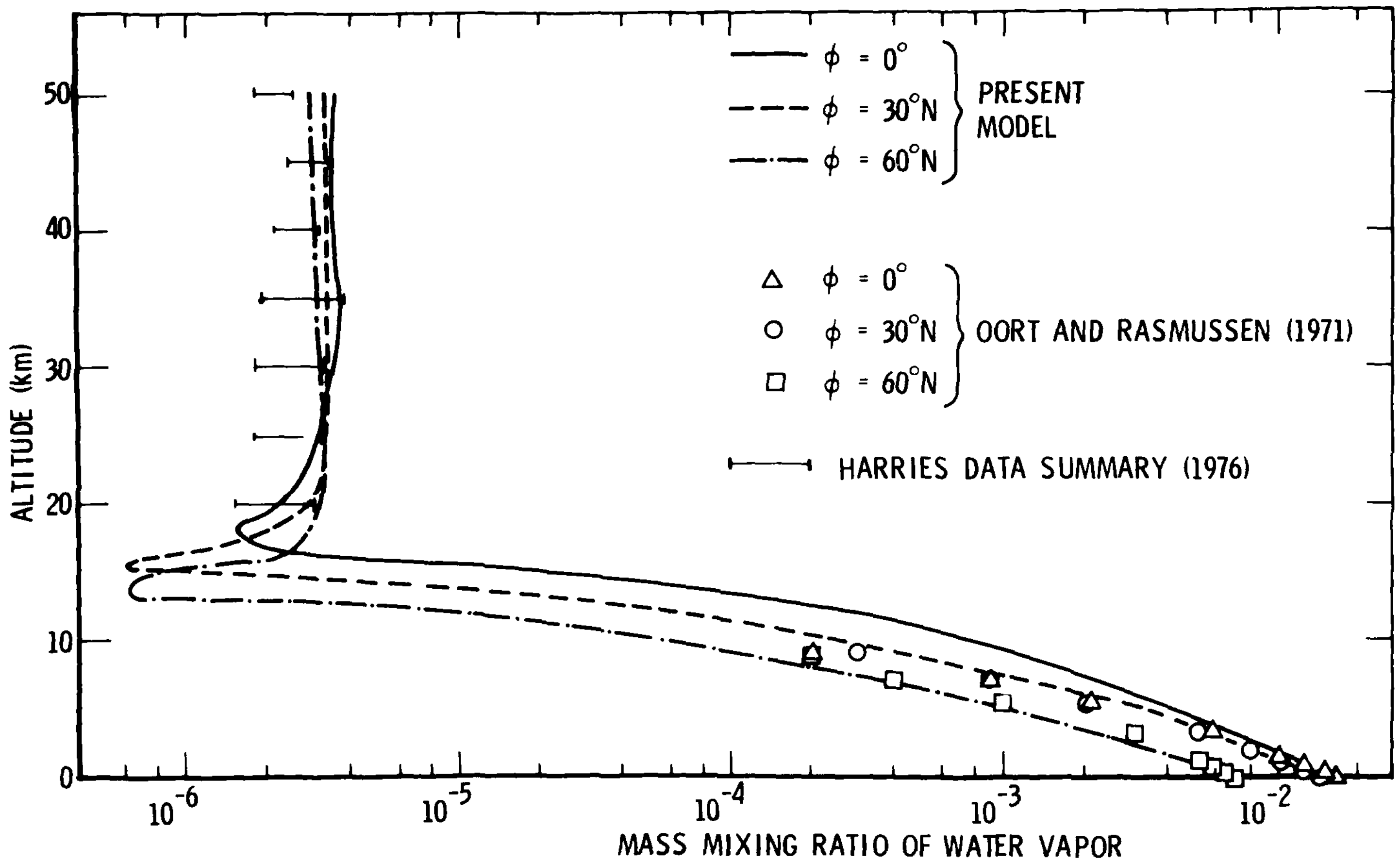


Fig. 5d. Water Vapor Profile in Natural Atmosphere in July

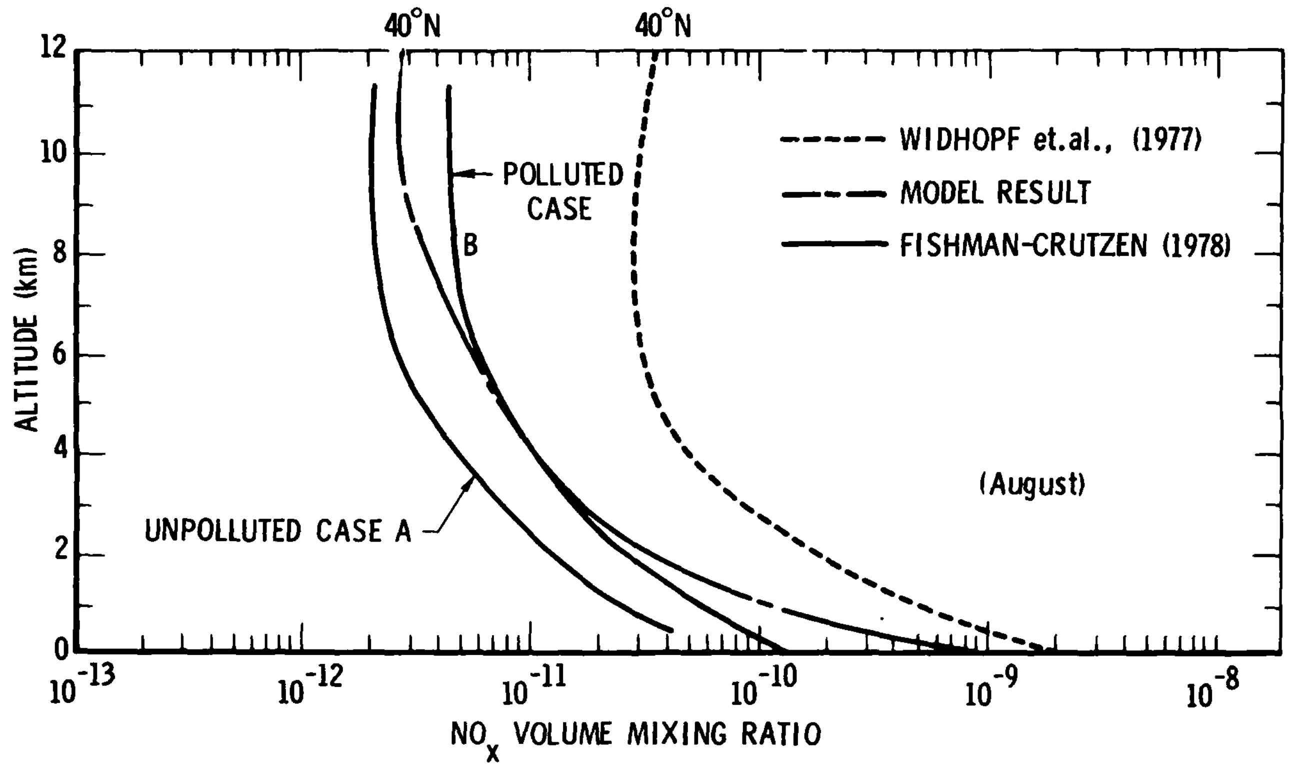
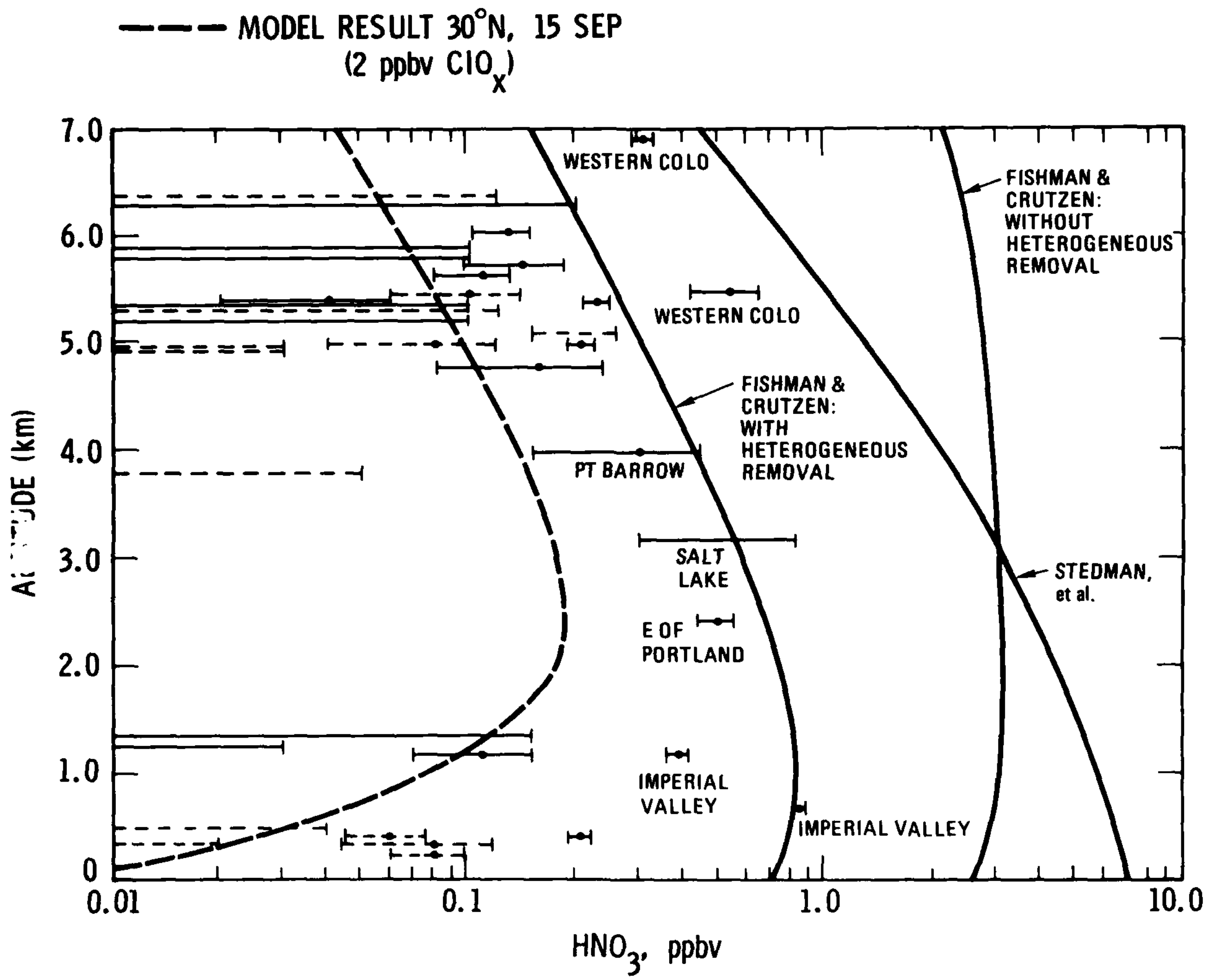


Fig. 6. Comparison of Calculated NO_x Profiles in Troposphere with Fishman-Crutzen Estimated NO_x Profiles

Tropospheric HNO_3 profiles at 30^oN latitude are compared in Fig. 7, with the corresponding measurements reported by Heubert and Lazarus (1978). Here, the data very near the surface have been used to evaluate the surface deposition velocity. This deposition velocity controls the shape of the profile below 2 km, while rainout controls the profile in the rest of the troposphere. This further indicates that this very simple rainout model provides an approximate means to simulate the average rainout process in the troposphere. It should be emphasized here that, at best, the rainout/washout is only simulated in some average sense.

While the calculated tropospheric level of HNO_3 seems to be in relative agreement with the limited available data, the concentration of HNO_3 is overpredicted in the stratosphere. This is shown in Fig. 8, where the computed HNO_3 columns above 12 km are compared to measurements. The predicted levels are a factor of approximately three to four higher than these observations. This is also demonstrated in Fig. 9, where a comparison is made of the computed profiles of NO, NO_2, and HNO_3 with the corresponding simultaneous measurements of these species in the stratosphere (Evans, et al. (1976)). The NO level is in good agreement with observations; however, the HNO_3 level is seen to be too high, and the NO_2 level is low.

The species HO_2NO_2 is a potential reservoir for some NO_x and HO_x and therefore may provide part of the solution to the partitioning of NO_y as described above. However, the inclusion of HO_2NO_2 in these simulations has not decreased the level of HNO_3 to values in much better agreement with data from that obtained in our previous calculations (Widhopf and Glatt (1979a)). Just recently, measurements of the photolysis rate which are lower than the recommended JPL NASA review rates used in these calculations have just been made available (Molina (1980)) and, thus, subsequent calculations using these lower photolysis rates may have a positive effect on the reduction of the HNO_3 level. The overprediction of HNO_3 above current observed levels needs extensive investigation. In particular, the chemistry



Dashed error-bars represent experiment marine values, solid bars are continental measurements, and curves are theoretical estimates. Locations are given primary for samples taken near populated areas. (After Huebert and Lazrus (1978))

Fig. 7. Predicted and Measured HNO_3 versus Altitude

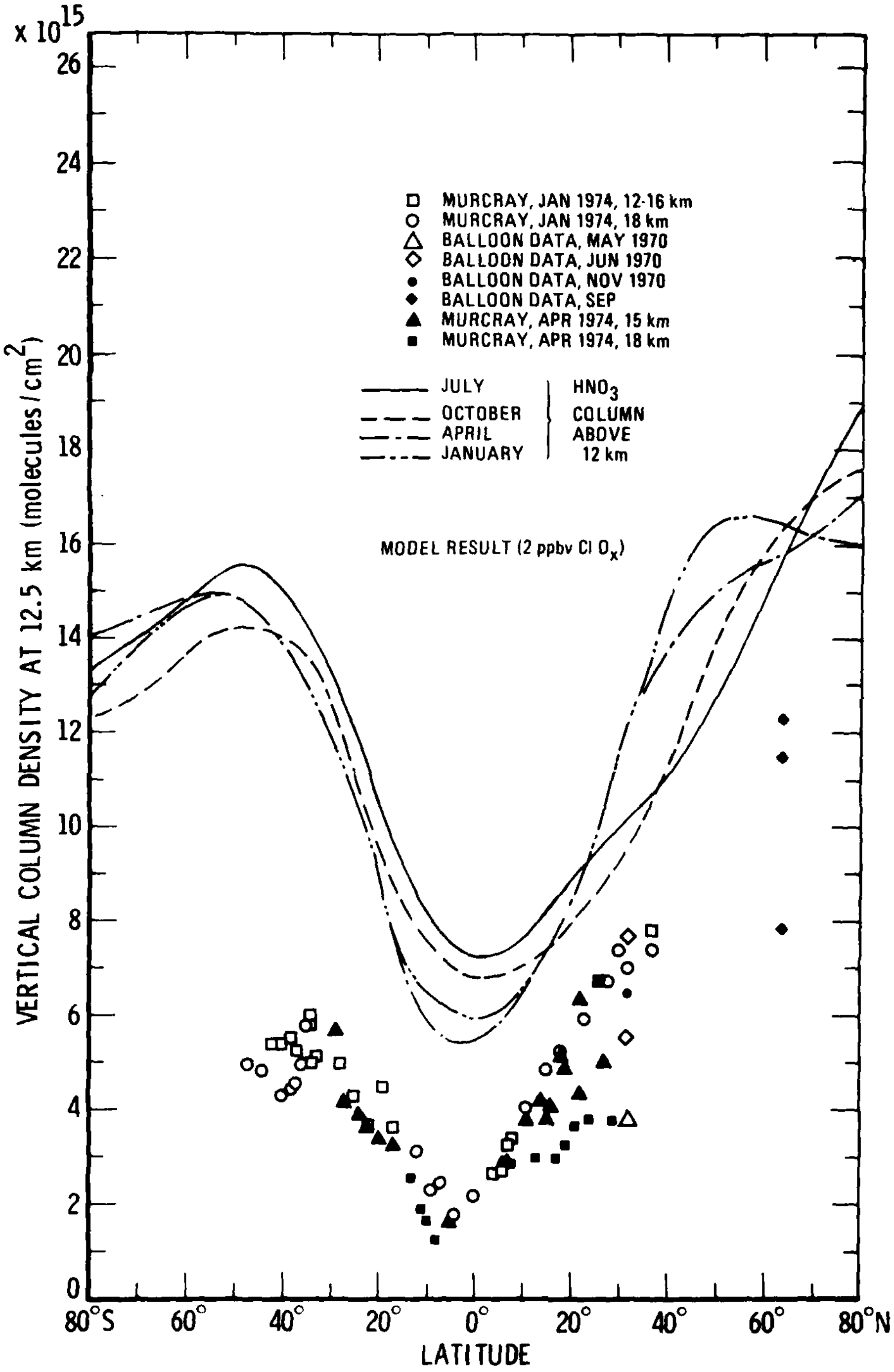


Fig. 8. Comparison of Calculated and Observed HNO_3 Column Variation with Latitude

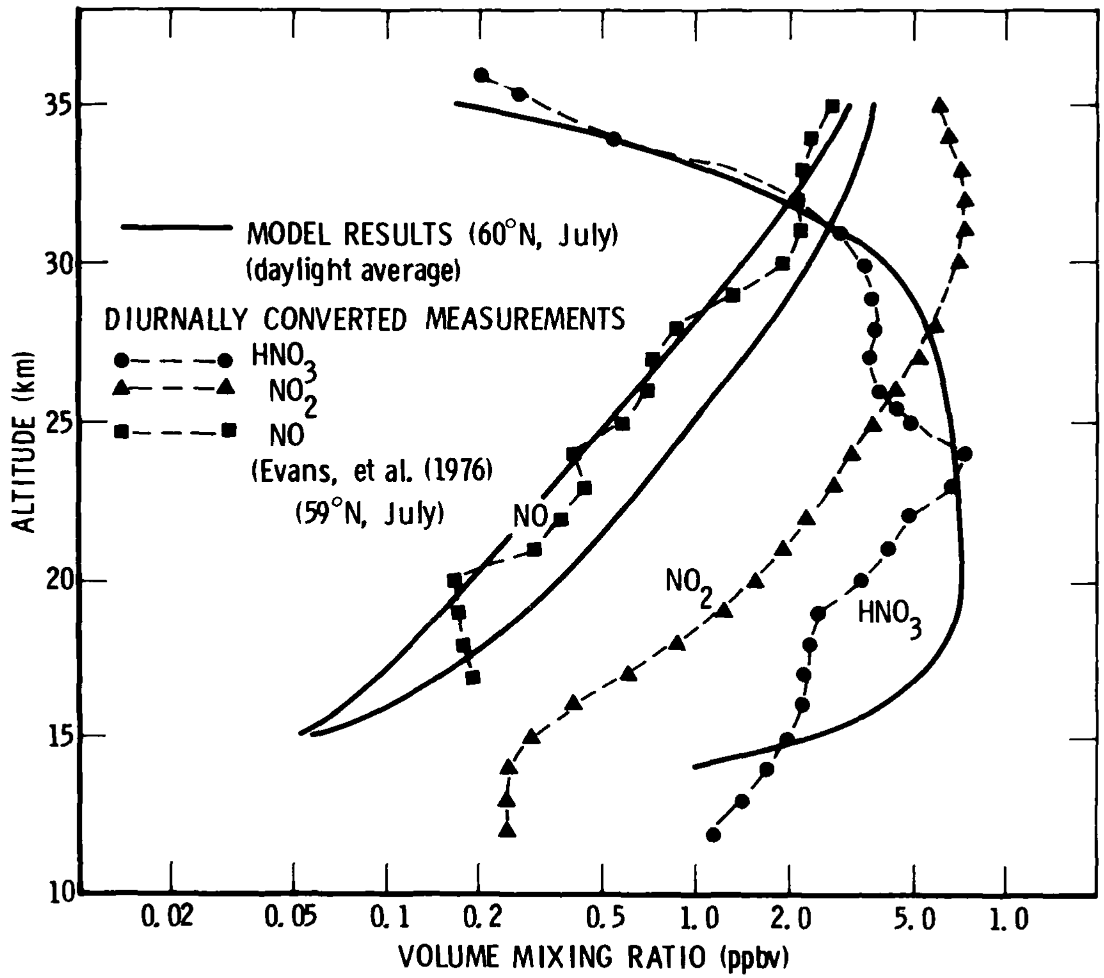


Fig. 9. Comparison of Calculated and Measured Profiles of NO, NO_2, and HNO_3

of OH needs additional attention, since this species also controls the calculated level of HNO_3. An important reaction which could also be a controlling mechanism is the reaction OH + HO_2NO_2. A definitive measurement is needed of the rate at which this reaction proceeds.

Since OH is a species which controls many of the important atmospheric chemical processes, the calculated distribution at 30°N during January is shown in Fig. 10 compared to some measurements in January 1976 (Anderson (1976)). The agreement in the high stratosphere is good, and the calculated profile is also within the broad regime of the tropospheric measurements. More data are needed in the troposphere and lower stratosphere in order to determine the adequacy of the OH calculations in this regime. This is the regime where the concentration of species which react readily with OH do not agree with measured levels (e.g., HNO_3, NO_2, CH_4, and CO).

Comparisons of the N_2O profiles calculated at different times of the year and locations are compared with data in Fig. 11. Below approximately 35 km, the model calculations are in relative agreement with data. Above 35 km, the calculated levels seem to be too high as compared to these limited measurements. A similar comparison for CH_4 is shown in Fig. 12. The general agreement is good except between 20 and 30 km. This, of course, is the region where OH data is lacking and a region where the reaction between OH and CH_4 is important.

A comparison with the limited data available for CO shows relative agreement with Seiler (1974) measurements in the troposphere; however, the calculated stratospheric level is low. The distribution of CO in the stratosphere also is controlled somewhat by its reaction with OH. Therefore, from all these comparisons of calculated and measured distributions of species directly affected by OH (HNO_3, CO, CH_4, etc.), it seems that more investigation is needed regarding the measurement of the levels of OH present in the atmosphere, especially within the altitude regimes of 15 to 30 km. Also,

more measurements of the rates at which OH reacts with many important species are needed. This information should help to clear up some of the differences modelers are presently obtaining between calculated and measured distributions of CH_4, CO, and the various components of NO_y.

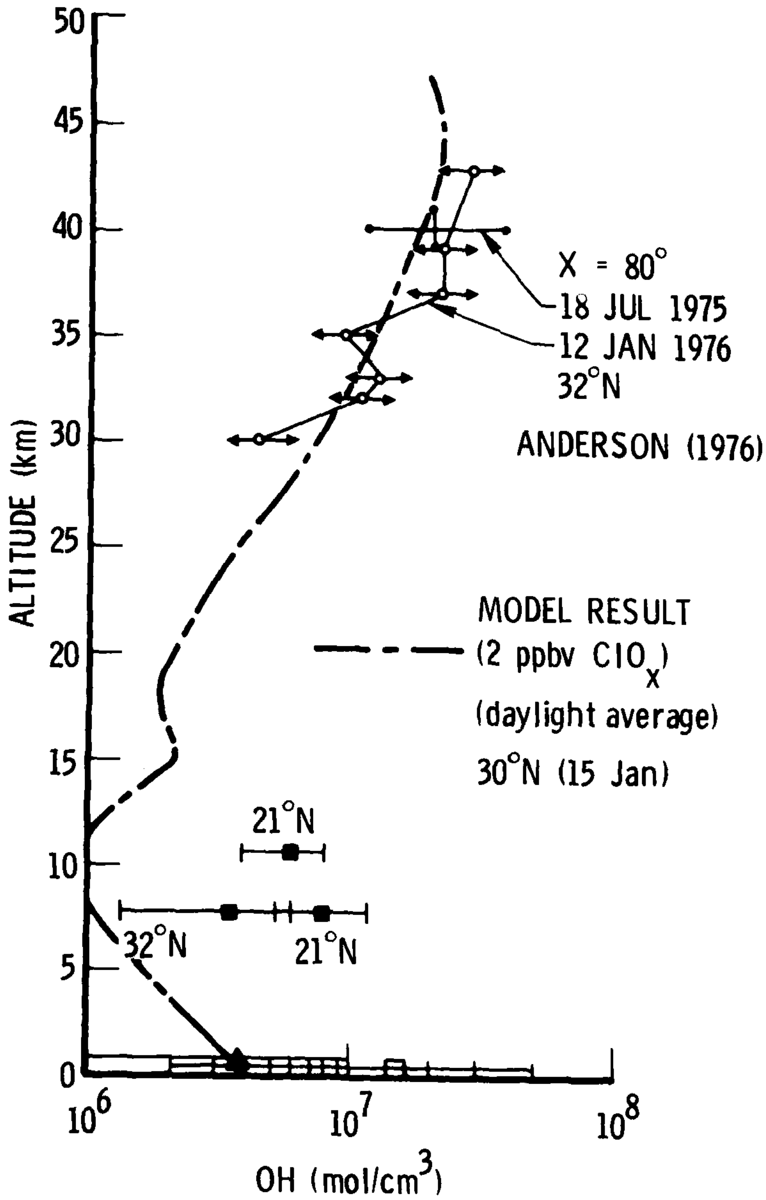


Fig. 10. Comparison of Calculated and Observed OH Concentration

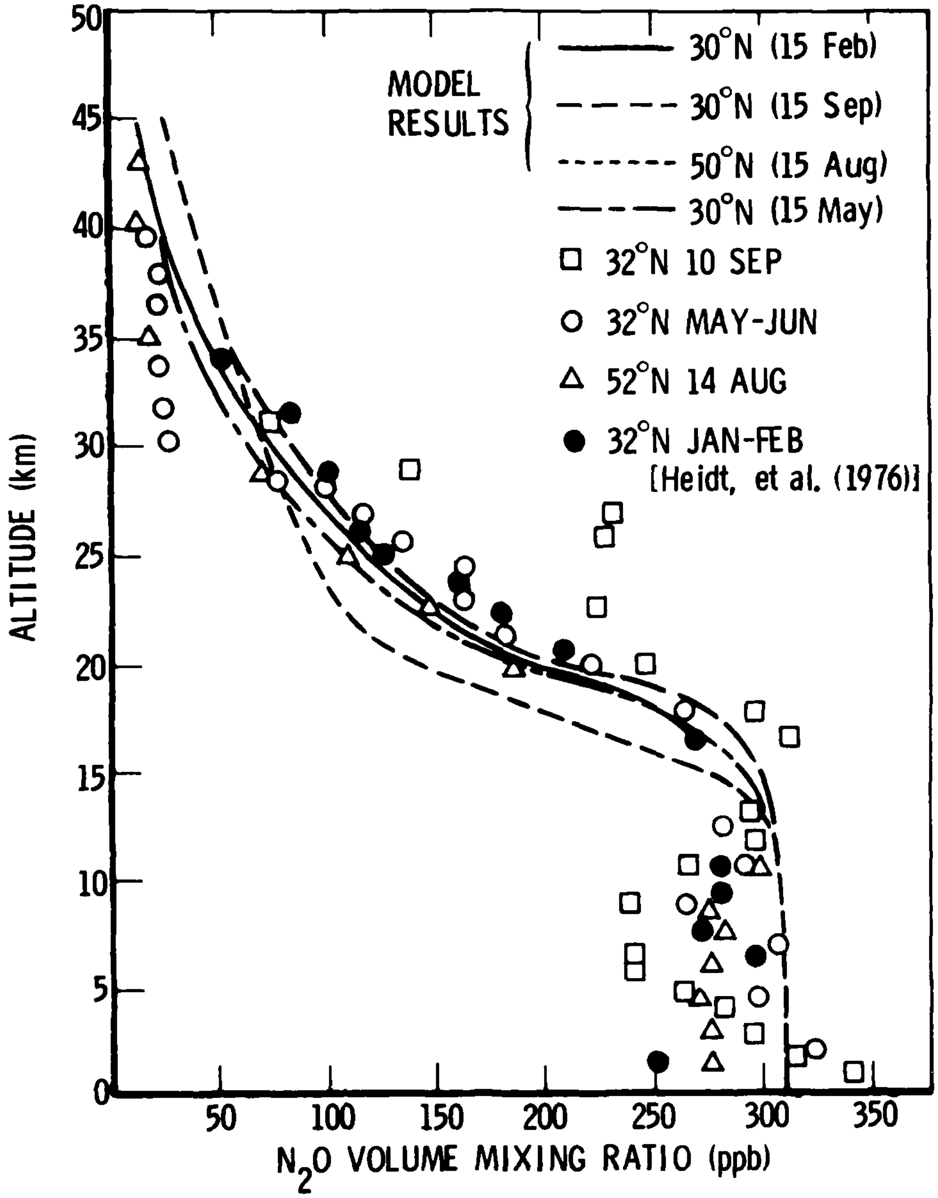


Fig. 11. Comparison of Calculated N_2O Profiles with Measurements

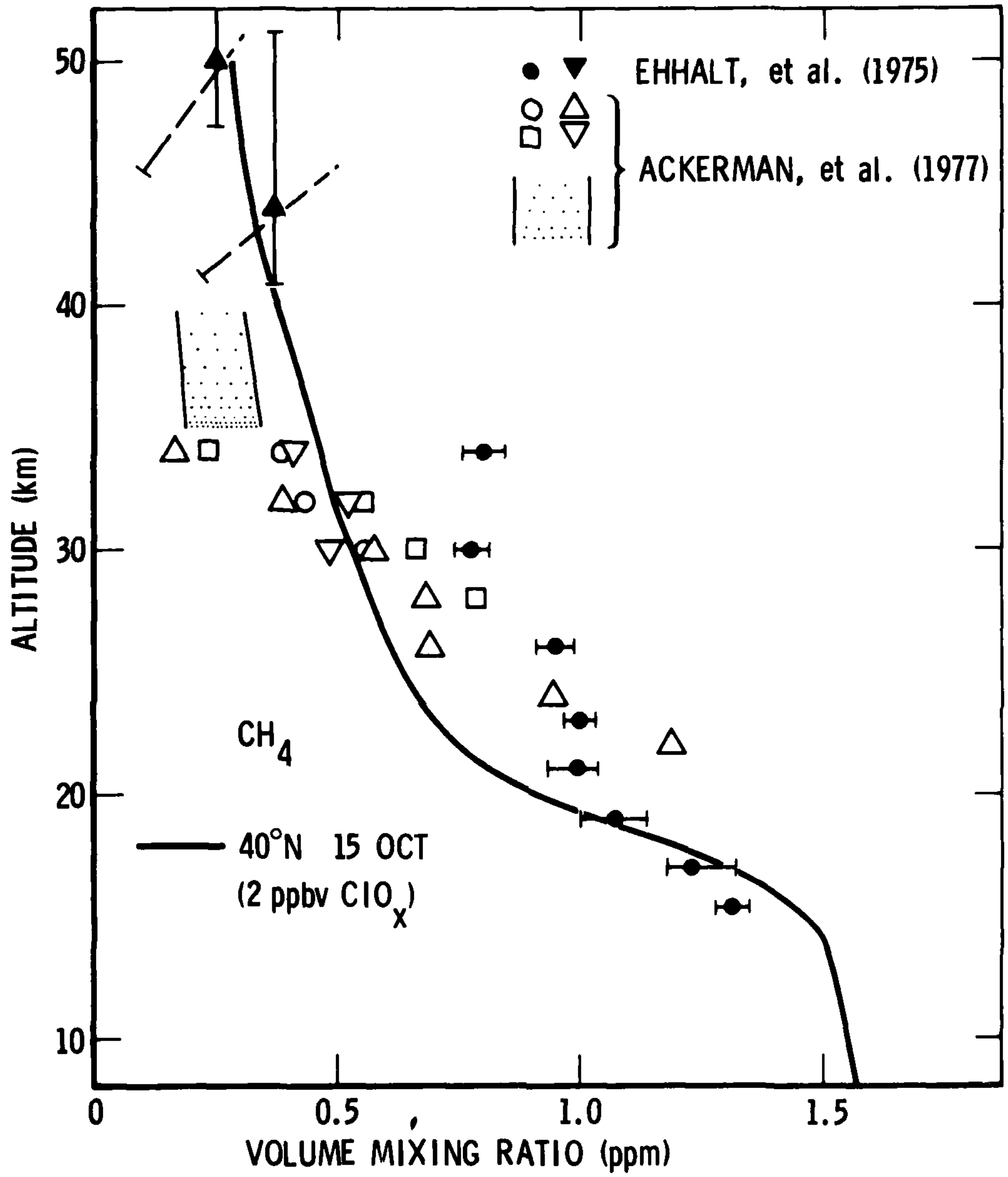


Fig. 12. Comparison of Calculated and Measured CH_4 Profile

9. AIRCRAFT EMISSIONS EFFECTS

The model has also been used to estimate the effect of aircraft emissions on the ozone layer. Emissions (see Table II) from a fleet of subsonic and supersonic aircraft projected to be operational in 1990 (Little (1976); Oliver (1976)) were introduced into a simulated 1990 natural atmosphere assumed to contain 2 ppbv ClO_x in the stratosphere. The effect of these emissions on the ozone layer is summarized in Fig. 13 which shows the ozone column change at various latitudes over a five-year period of continuous aircraft fleet operation starting in February. An increase in ozone column occurs at all latitudes depicted and also at all other latitudes not shown. A slow increase over the five-year interval is apparent with the fifth year closely approximating the fourth year. From previous experience using this model, a "steady state" would be achieved in about seven years, with minor changes from the results of the fifth year. Thus, the simulation was only carried out for five years to reduce computational costs. The ozone column change above 17 km is also depicted using a highly expanded scale showing the slow increase occurring at higher altitudes, due to transport.

The latitudinal distribution of these resultant changes in total ozone column during October, July, April, and January of the fifth year of simulation is shown in Fig. 14. Shown in the insert is the total amount of NO_2 injected at each latitude. Note that the peak ozone change (≈ 3.8 percent) occurs at 30 to 40^oN in October (corresponding to the latitudes for peak injection) and moves slightly southward, peaking about 20 to 30^oN during April. This transport effect has been observed in previous calculations by Widhopf, et al. (1977). Thus, the present simulations also show a definite corridor effect as was present in previous estimates of NO_x pollution effects (Widhopf, et al. (1977); Widhopf and Glatt (1978), 1979a,b)). The effect in the southern hemisphere is much smaller than the perturbation in the northern hemisphere as a result of the injection scenario used in these calculations. However, interhemispheric transport has resulted in an average

Table II. 1990 Worldwide Aircraft NO_x Emissions, High Estimates, kg/yr*

	ALTITUDES - km												
Latitude	6-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	Total
N 60+	3.35E6	3.03E6	1.43E7	1.31E7	1.46E7	1.31E6	9.99E5	4.06E5	1.72E6	2.59E6	2.10E6	1.43E6	5.894E7
50-60	2.15E7	2.59E7	9.44E7	1.06E8	9.09E7	8.26E6	3.72E6	2.12E6	6.57E6	1.03E7	8.06E6	3.71E6	3.814E8
40-50	7.60E7	8.70E7	1.79E8	2.79E8	1.62E8	2.48E7	4.59E6	2.09E6	4.17E6	6.96E6	5.46E6	2.36E6	8.334E8
30-40	7.74E7	9.20E7	1.67E8	3.09E8	1.72E8	2.97E7	3.11E6	1.74E6	1.30E6	2.73E6	2.07E6	8.63E5	8.589E8
20-30	2.61E7	2.83E7	6.74E7	1.02E8	6.92E7	8.73E6	1.55E6	1.20E6	8.06E5	1.90E6	1.71E6	4.67E5	3.094E8
10-20	1.11E7	1.18E7	2.65E7	4.28E7	3.99E7	3.67E6	4.74E5	1.54E5	3.24E5	5.38E5	4.22E5	1.71E5	1.379E8
0-10	4.80E6	5.14E6	1.50E7	1.82E7	1.36E7	1.26E6	1.73E5	0	2.91E5	4.08E5	3.44E5	1.63E5	5.938E7
10-0	3.31E6	3.77E6	1.22E7	1.38E7	1.09E7	8.65E5	1.38E5	0	3.01E5	4.22E5	3.56E5	1.65E5	4.623E7
20-10	2.74E6	3.21E6	1.14E7	1.52E7	1.15E7	1.11E6	3.15E5	1.32E5	1.10E5	2.19E5	1.58E5	7.52E4	4.617E7
30-20	3.67E6	4.01E6	9.47E6	1.37E7	8.66E6	9.31E5	5.10E4	0	9.85E4	1.38E5	1.16E5	6.63E4	4.091E7
40-30	4.01E6	4.63E6	6.62E6	1.18E7	6.14E6	1.21E6	8.64E4	5.16E4	1.56E4	4.74E4	2.84E4	6.22E3	3.464E7
50-40	2.36E5	3.05E5	3.19E5	8.28E5	4.46E5	9.29E4	1.5 E1	0	0	0	0	0	2.227E6
60-50	4.77E4	3.79E4	2.99E4	2.52E4	1.04E4	1.45E3	0.97	0	0	0	0	0	1.526E5
S 60+	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2.343E8	2.691E8	6.036E8	9.255E8	5.999E8	8.197E7	1.521E7	7.894E6	1.571E7	2.625E7	2.082E7	9.477E6	2.810E9

*Oliver, R.C. [1977] and Little, A.D. [1976]

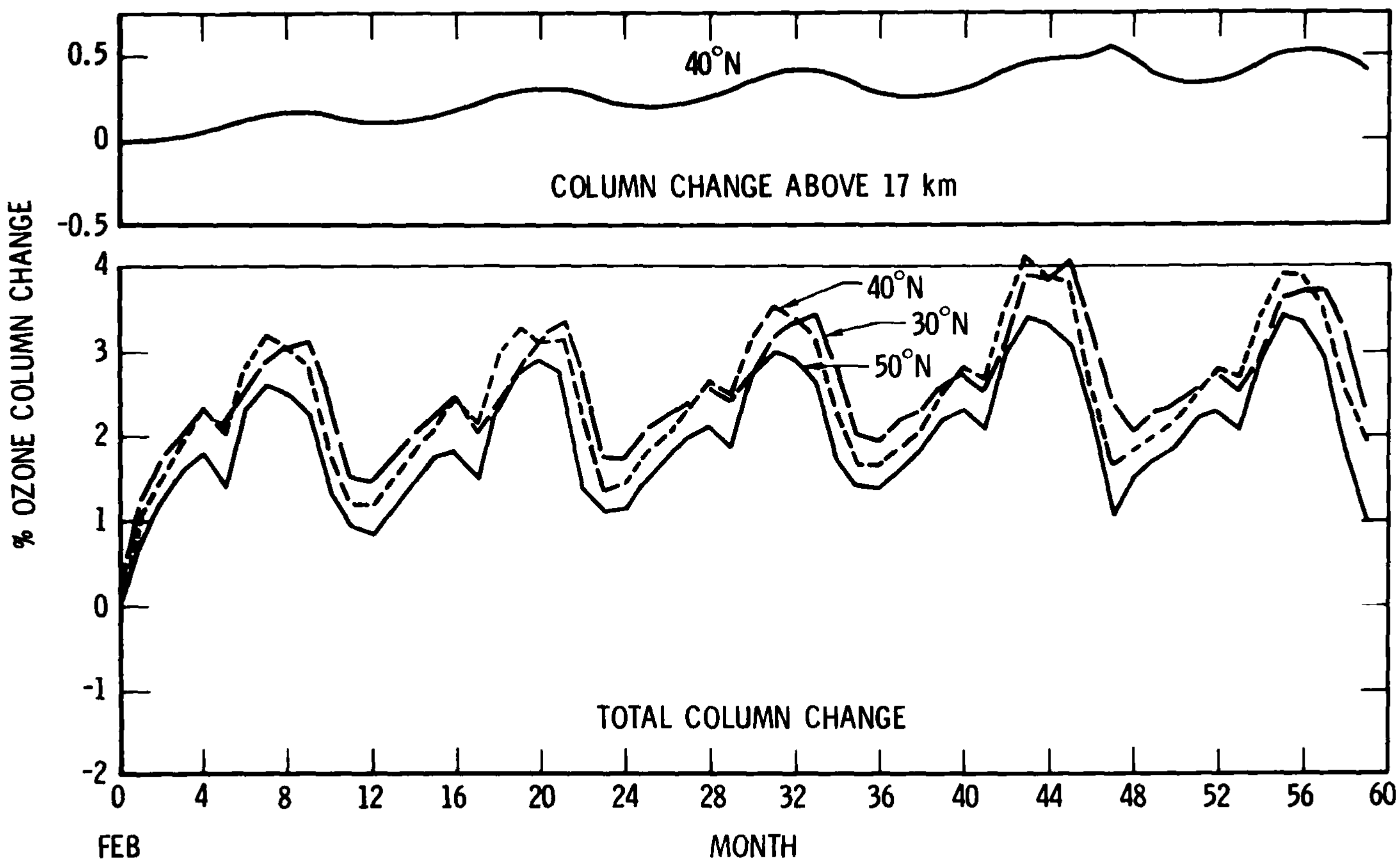


Fig. 13. Calculated Temporal Ozone Column Change Resulting from NO_x Emissions from a Combined Subsonic and Supersonic Fleet of Aircraft (Table II)

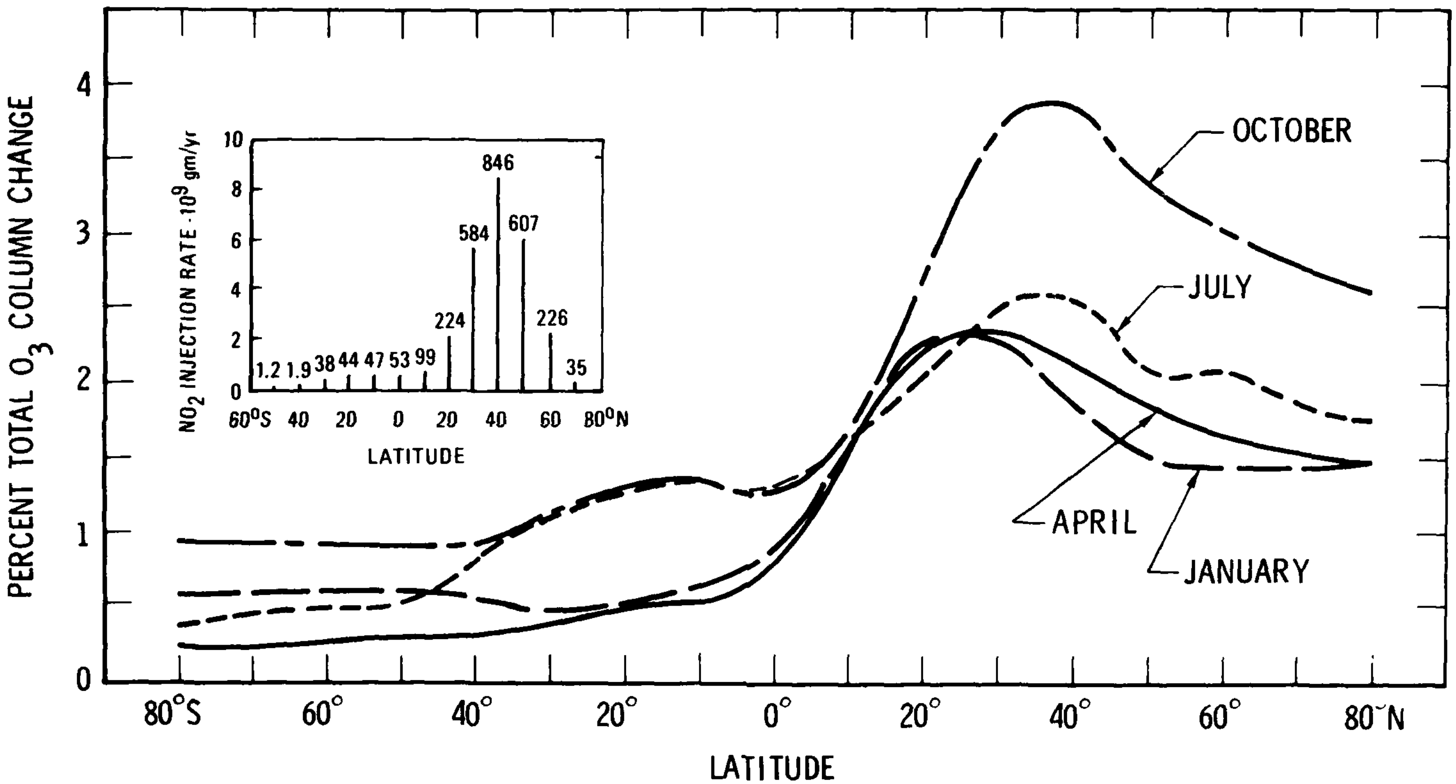


Fig. 14. Calculated Monthly Variation of the Total Ozone Column Change as a Function of Latitude

level of change, approximately 0.5 to 0.75 percent in the ozone column in the southern hemisphere where the primary change in the southern hemisphere occurs at low latitudes.

Figure 15 shows the percent change in ozone column with altitude at 20^o, 30^o, 40^o, and 50^oN latitude during the months of October, January, April, and July of the fifth year of aircraft operations. Above approximately 15 km, the change in ozone column is less than 0.75 percent, with the major fraction of the change occurring in the troposphere throughout the year. Above 25 km the ozone column change occasionally went negative. However, the magnitude never exceeded 0.1 percent.

Using a yearly averaged height of the tropopause, the latitudinal variation of the tropospheric and stratospheric contributions to the ozone column change was calculated; the distributions are depicted in Fig. 16. In the northern hemisphere, the major effect occurs in the troposphere south of 40^oN. At the higher latitudes, the tropospheric and stratospheric effects are comparable, a result of the lower tropopause height in relation to the aircraft cruising altitudes and the effect of meridional transport.

Altitude profiles are shown in Fig. 17 of the resultant perturbation of ozone and NO_x concentration at 40^oN during April, July, October, and January. Below 25 km the change in ozone resulting from the NO_x aircraft emissions is positive at all altitudes. The major changes are in the troposphere at the altitudes where the largest injection of NO_x occurs. The profiles of the changes in O_3 and NO_x are quite similar with some effect of transport on the O_3 profiles.

The monthly variation of the northern and southern hemispheric total ozone column changes are depicted during the fifth year of operations in Fig. 18, together with the corresponding globally averaged variation. Also shown are the yearly average of these quantities. The yearly average in the southern hemisphere is about one-third of the change which occurs in the

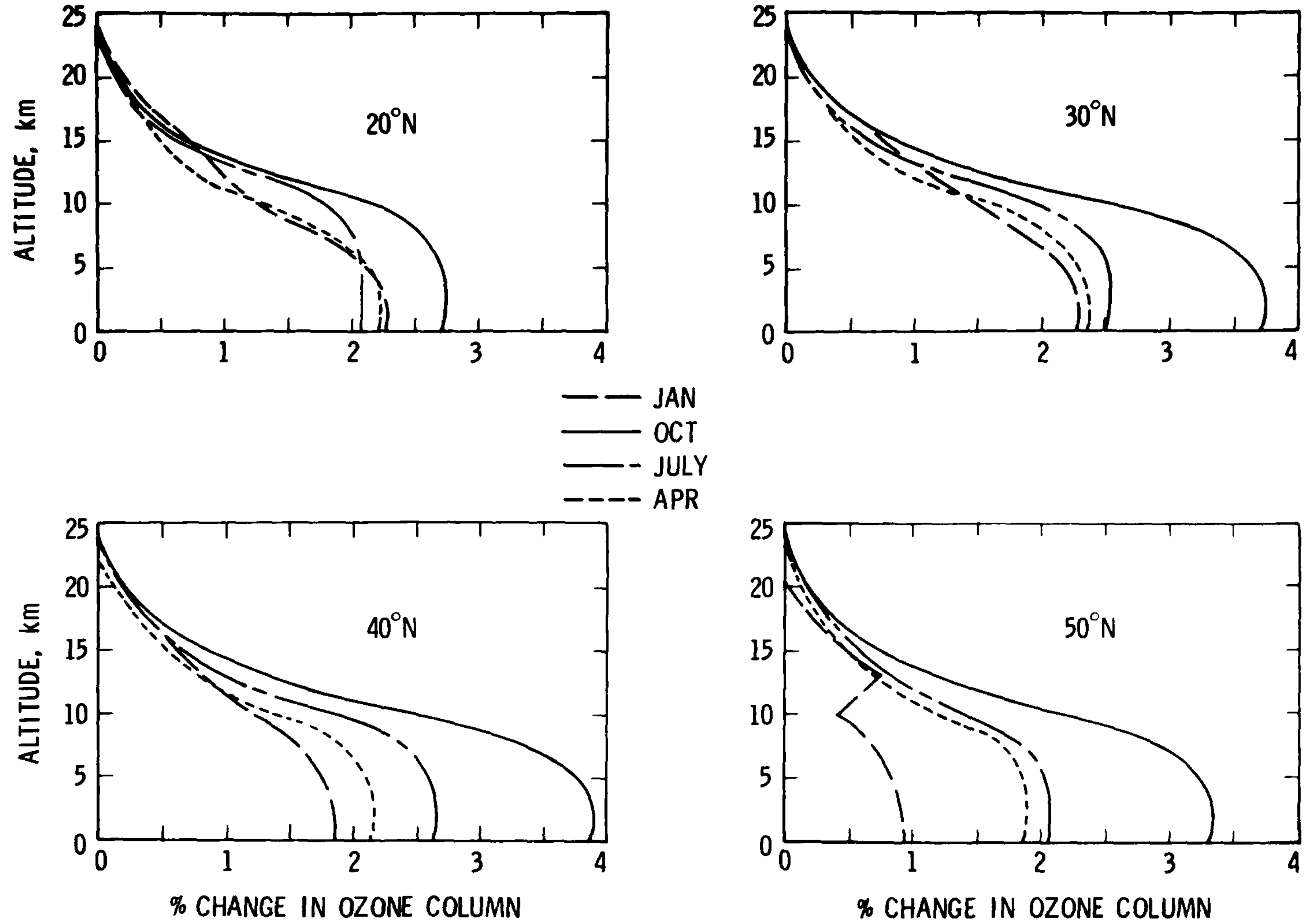


Fig. 15. O_3 Column Change as a Function of Altitude

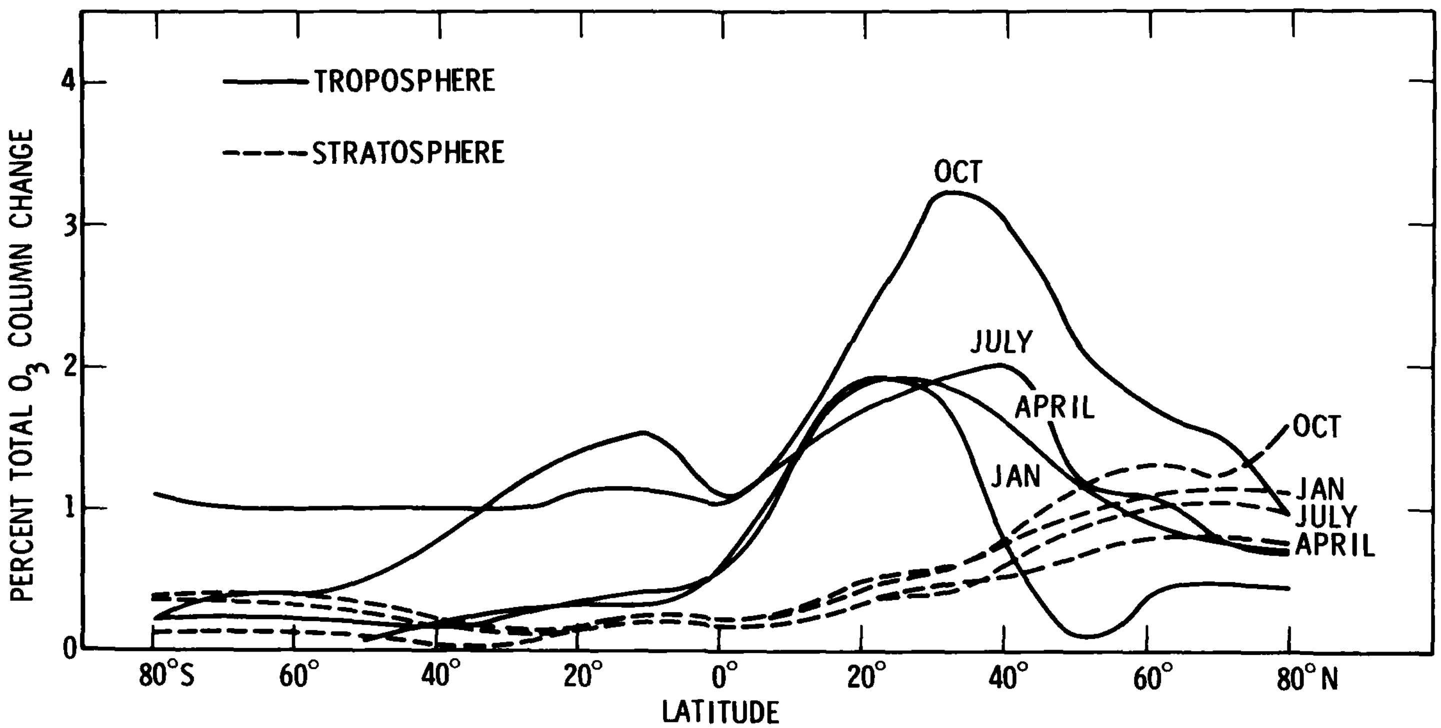


Fig. 16. Latitudinal Variation of O_3 Column Changes in Troposphere and Stratosphere

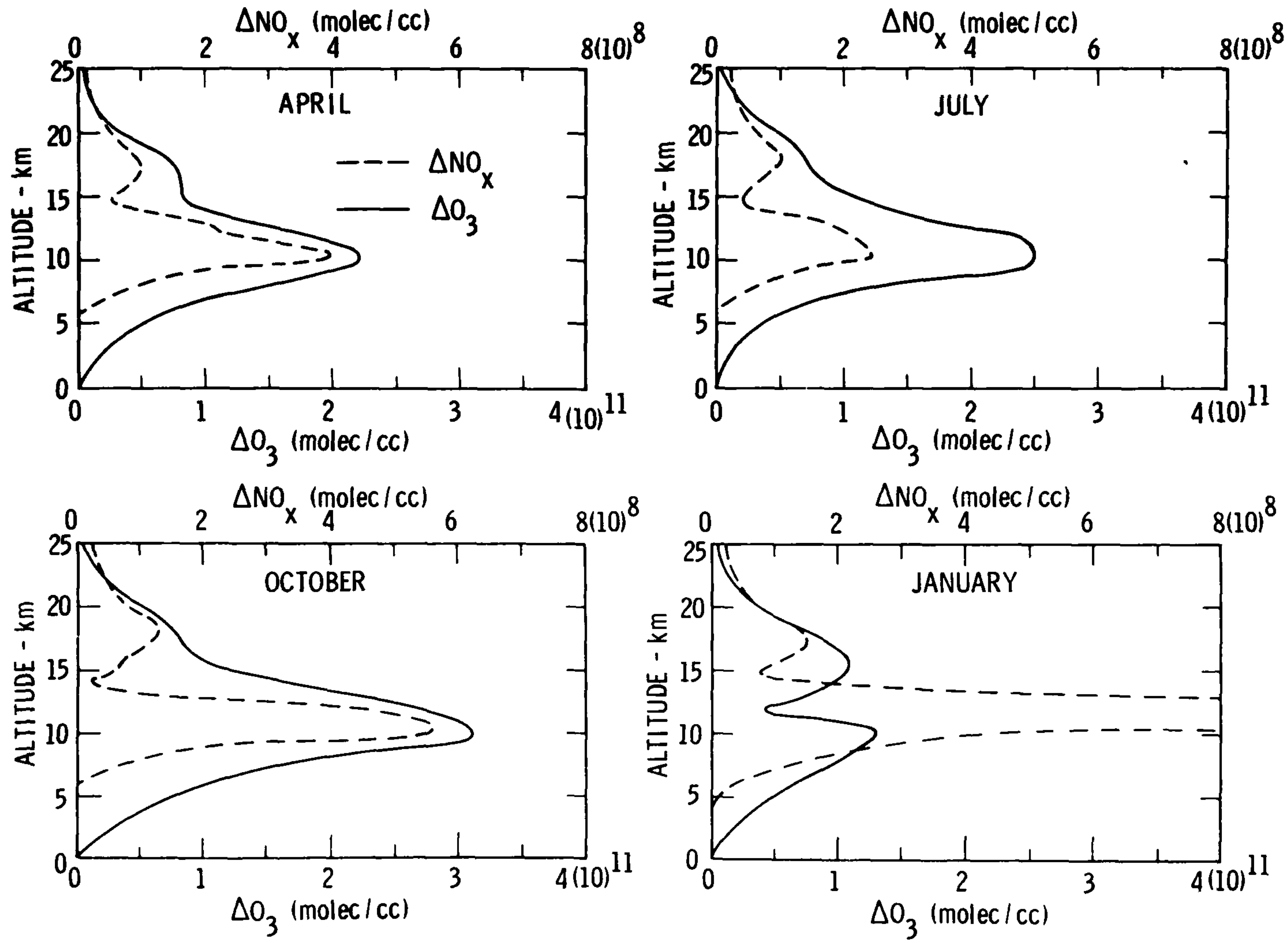


Fig. 17. Vertical Change in Ozone and NO_x Concentration at $40^{o}N$

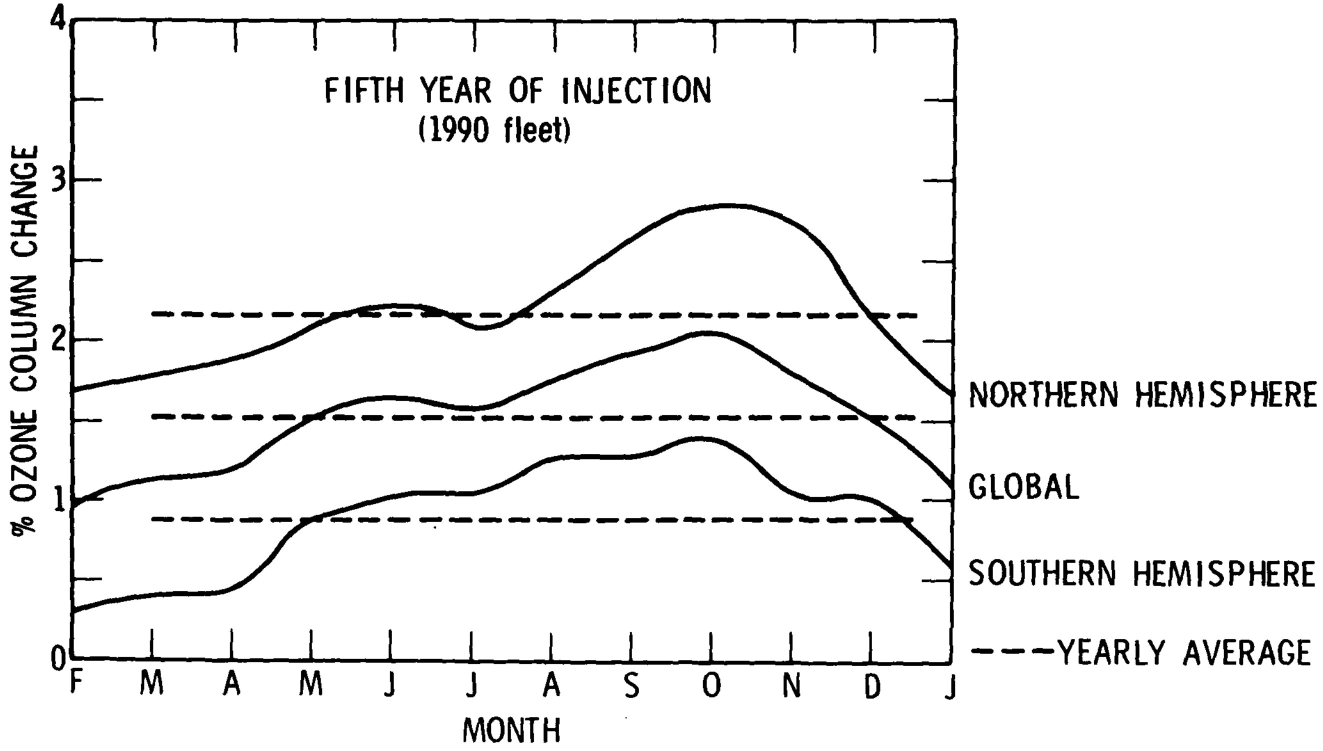


Fig. 18. Monthly Variation of the Northern and Southern Hemispheric and Globally Averaged Total O_3 Column Changes

northern hemisphere (2.2 percent), where the predominant contribution in the southern hemisphere occurs between 0^{o} and 30^{o}S. Averaged over the entire year, the global average is approximately 1.5 percent. The monthly variations above these yearly averages are quite large for all of these quantities.

In previous calculations using the same rates of NO_x emissions (Widhopf, et al. (1977)), ozone was found to be produced as a result of the NO_x emissions emitted from subsonic aircraft flying below approximately 13 km. This ozone was produced through the "smog" chemical cycle initiated by the oxidation of methane by OH. The NO_x emissions from higher flying aircraft were found in that study to slightly deplete ozone through the NO_x catalytic cycle. The overall results for the combined fleet of subsonic and supersonic aircraft was a slight increase (maximum local increase of 1.5 percent) in ozone column. These more recent model results predict that not only do low-flying aircraft emissions produce ozone in the troposphere, but even the emissions from high-flying supersonic aircraft produce small amounts of ozone. This is in agreement with some of our more recent calculations (Widhopf and Glatt (1978), (1979a,b)) and is primarily a result of the recent increase in the rate at which the reaction $NO + HO_2 \longrightarrow NO_2 + OH$, which is now approximately a factor of 40 larger than previous estimates. A discussion of the pertinent chemical mechanisms is included in the cited references and not repeated here, since there have not been any changes with these results.

The simultaneous introduction of water vapor was also performed in this present study and found to decrease the magnitude of the ozone increase resulting from the NO_x emissions above. However, for this particular fleet, the magnitude of the effect of the H_2O emissions is small (less than 0.1 percent in local ozone column) because, for these flight altitudes and this fleet size, the perturbation to the natural atmospheric H_2O distribution is minor. In the stratosphere, the effect of H_2O emissions results from the increased conversion of NO to NO_2 through the reaction $NO + HO_2 \longrightarrow NO_2 + OH$, which in turn resulted from the increased level of HO_2 which was chemically produced from the H_2O emissions. In the troposphere, the excess H_2O increases the level of OH which reacts with NO_2 forming HNO_3, which

eventually is rained/washed out. Both processes result in the removal of some of the NO_x aircraft emissions, decreasing the level of O_3 increase which results from aircraft NO_x emissions alone. This general result was also found to be the case in previous studies (Glatt and Widhopf (1978); Widhopf and Glatt (1979a,b)), and the reader is referred to those discussions for further details.

It should be emphasized that for different aircraft fleets, depending on the fleet size and the specific cruising altitudes, the relative magnitude of the effects of NO_x and H_2O emissions can be different than found for this fleet. It should also be emphasized that these estimates are dependent upon our present capability to model all the important mechanisms controlling this phenomenon, which are being modeled rather than computed from first principles. Our present state of knowledge in some of these areas is deficient, and future improvements may change these results. The most important areas needing improvement are the transport prescription in the upper troposphere-lower stratosphere, the modeling of rainout/washout phenomena and the specification of the tropospheric chemistry.

A basic step in the development of a model for describing rainout/-washout phenomena has recently been taken by Isaksen and Rodhe (1978) which will allow for improved modeling of these complex phenomena. An approach of this type will be used in subsequent model studies.

10. SOLAR PROTON EVENT

It has been recognized that solar proton events can produce significant amounts of NO at high geomagnetic latitudes ($> 60^{o}N$), and that definite ozone changes have been observed during and after these events. As pointed out by Crutzen, et al. (1975), the increase in NO is due to the dissociation of nitrogen by electrons with energies in the range of tens to hundreds of electron volts. The primary reactions that lead to the production of NO are

$$N_2 + e \longrightarrow N_2^+ + 2e \qquad (1a)$$

$$N_2 + e \longrightarrow N^+ + N + 2e \qquad (1b)$$

$$N_2 + e \longrightarrow 2N + e \qquad (1c)$$

These reactions lead to ionization and dissociation of nitrogen, while the following reactions produce NO:

$$N^+ + O_2 \longrightarrow N + O_2^+ \qquad (2a)$$

$$N^+ + O_2 \longrightarrow NO^+ + O \qquad (2b)$$

$$N + O_2 \longrightarrow NO + O \qquad (2c)$$

$$N + O_3 \longrightarrow NO + O_2 \qquad (2d)$$

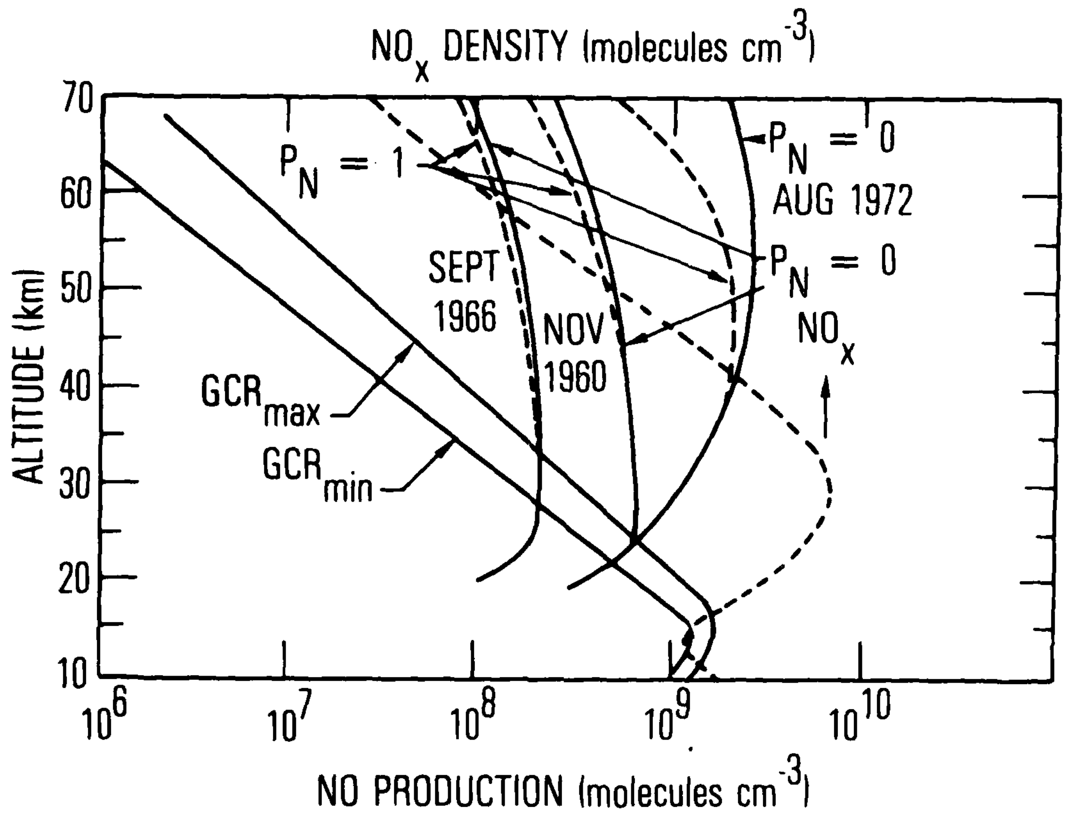
Reaction 2c is temperature-dependent and is slow for nitrogen in the ground state ($N(^4S)$). However, this is not the case for the electronically excited state atom ($N(^2D$ or $^2P)$); thus, the amount of NO produced during the solar proton event depends on the electronic state of the nitrogen atom.

Crutzen, et al. (1975) examined three solar proton events which occurred in November 1960, September 1966, and August 1972 and computed the total production of NO during these events. Figure 19 shows the results of their calculations which were performed assuming that (a) all the nitrogen atoms were in ground state and (b) all nitrogen atoms were in excited states (^2P, ^2D). In addition, they included the NO destruction reaction

$$N + NO \longrightarrow N_2 + O \qquad (3)$$

These results show that the August 1972 event was the strongest of the three events. The number density profiles shown are an average distribution for the region north of about 60° latitude. In their calculations, it was assumed that the production rate of NO was about 1.5 times the ionization rate. However, in a recent paper by Fabian, et al. (1979), they have inferred from rocket measurements of mesospheric and thermospheric nitric oxide concentrations during auroral particle precipitation events (Arnold (1978)) that the molecule/ion pair ratio is 2-2.5. In addition, Jackman, et al. (1979) have determined upper bounds on the NO production rate below 80 km and found the ratio to be 1.2-1.3, which is closer to that used by Crutzen, et al. (1975).

Due to the large controversy involving the NO production rate and the recent numerous chemical reaction rate changes since both Heath, et al. (1977) and Fabian, et al. (1979) performed their investigations, it was felt that application of the present model to the August 1972 solar proton event (the strongest recorded in 25 years) would be a good test of the present model chemistry and transport.



Total production of NO during the solar proton events of November 1960, September 1966, and August 1972 (lower scale) is given for heights between 70 and 20 km. The curves labeled $P_N = 0$ and $P_N = 1$ give the production obtained by assuming that all nitrogen atoms are in excited ($^2P^2D$) states and in the ground ^4S) state, respectively. The total maximum (GCR_{max}) and minimum (GCR_{min}) annual production of NO from galactic cosmic rays are included. The adopted background distribution of NO_x ($NO + NO_2$) is also given (upper scale).

Fig. 19. Production of NO During Various Solar Proton Events (After Crutzen, et al. (1975)).

Since the chemical reaction system in this model does not include all the appropriate reactions to simulate the solar proton event, it was decided to use the NO production calculations of Crutzen, et al. (1975) and introduce these NO perturbations at the onset of the solar proton event. To study the sensitivity of the results to the molecule/ion pair ratio, we also increased the NO production by the factor 1.7 (ratio 2.5/1.5). In addition, the reported calculations of Crutzen, et al. (1975) were an average over the latitudes north of 60^{0}, and thus no latitudinal distribution of the NO production was available. Therefore, for the initial calculations, NO was uniformly inserted at all latitudes north of 60^{0} using the results (Fig. 19) for the exited nitrogen state. The natural atmosphere was simulated over a number of years in order that a periodic solution existed. On 4 August, the NO profiles were added to those calculated for the undisturbed atmosphere with 2 ppbv ClO_x, and the model was run for one day using an initial time step of 0.1 sec. At the end of one day, the calculation was restarted using a one-day time step, and the calculation was carried out until 4 September 1972.

Figure 20 shows the change in a *zonally* averaged ozone column above 37.5 km ($\simeq$ 4 mbar) at 75 to 80^{0}N. The data were obtained from the BUV experiment on the Nimbus 4 Satellite (Heath, et al. (1977)). Also shown are the results of the simulation fo: both 1.5 molecules/ion pair and 2.5 molecules/ion pair at 80^{0}N. For the case which considers 1.5 molecules/ion pair, the initial drop in O_3 column is about 3.5 units. Here the zero value was chosen to be the level of the natural atmosphere ozone column just prior to the event. The recovery period is about two weeks for this case. For the higher value of NO production rate, an initial drop of about 5.2 units is observed; by the end of the simulation, the ozone column has still not completely recovered.

Figure 21 shows the resultant distribution of O_3 reduction at 80^{0}N for the case 1.5 molecules/ion pair. At t=0+ the event had just occurred, and a peak reduction in O_3 of about 27 percent is calculated at 45 km. Below 25 km there is essentially no effect on O_3. Results also are presented for t=8, 19, and 29 days after the event. Note that after 29 days the ozone has

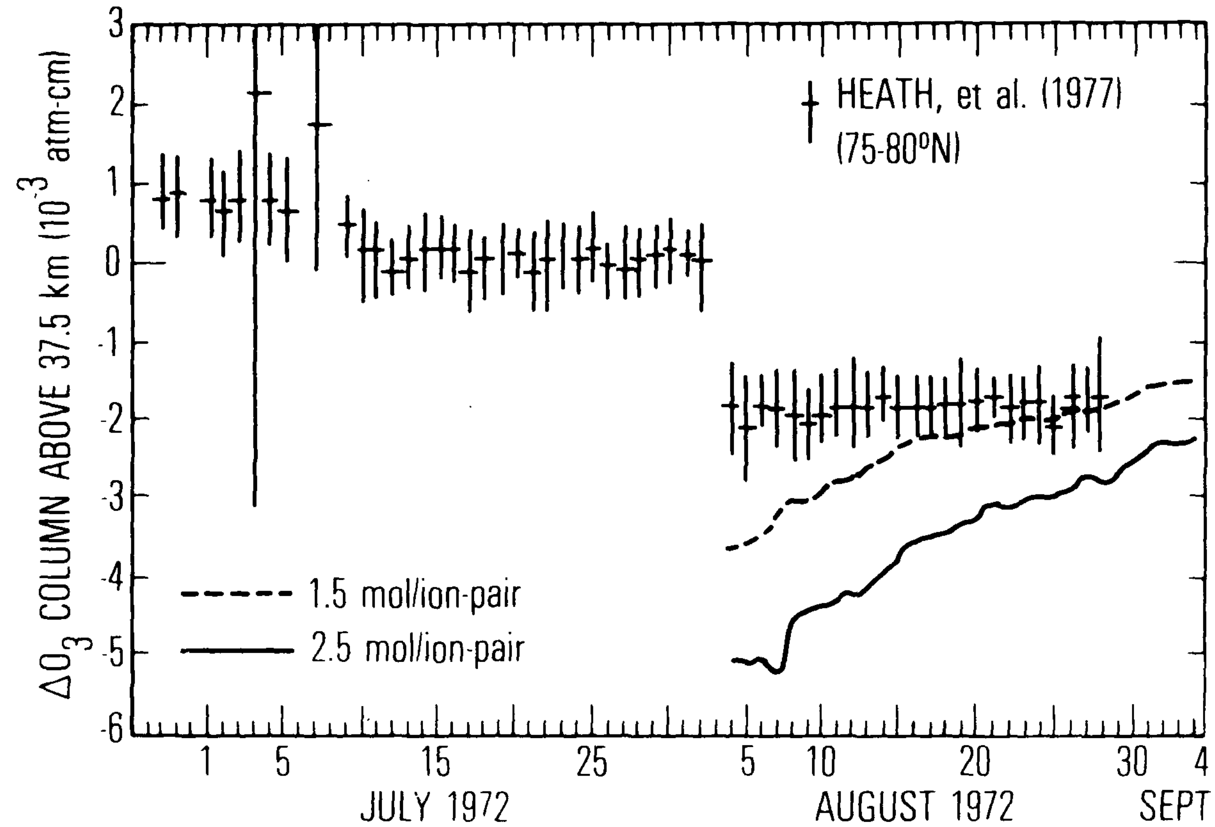


Fig. 20. Comparison of Calculated and Measured O_3 Column Change from August 1972 Solar Proton Event

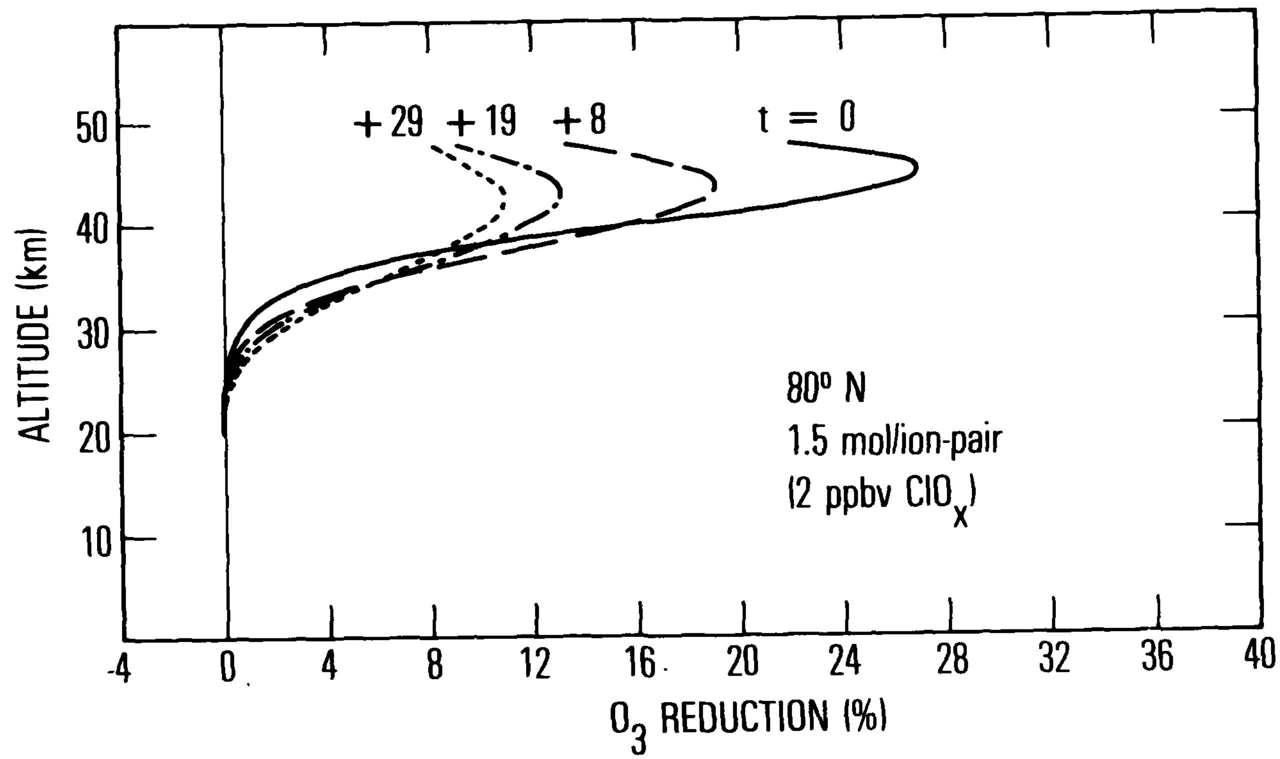


Fig. 21. Calculated Relative Reduction in Ozone Concentration with Time After Solar Proton Event (1.5 molecules/ion pair)

recovered somewhat, and the peak reduction is about 11 percent at about 42.5 km. Figure 22 shows the resultant ozone reduction for the case of 2.5 molecules/ion pair case. Here it is seen that at t=0+ about a 38 percent reduction occurs at 45 km, whereas after 29 days the ozone reduction has decreased to about 18 percent. Shown in Fig. 23 is the zonally averaged O_3 column change between 55^o and 65^oN latitude taken from Nimbus 4 data (Heath, et al. (1977)). Also shown are the results of the model simulation at 60^oN. These results are qualitatively in agreement with those at 80^oN; however, the levels of O_3 reduction are slightly higher with the calculation using 1.5 molecules/ion pair case showing about 4.2 units and the higher case showing about 6 units. Although not shown, there is essentially no effect on O_3 south of 50^oN.

Figure 24 shows the results obtained by Heath, et al. (1977) in which they used a two-dimensional, zonally averaged model with 1977 chemical rates to simulate the 1972 solar proton event. After 28 days the results show about a 15 percent peak reduction in O_3 about 45 km. For this calculation the molecule/ion pair ratio was taken to be 1.5.

In a recent paper by Fabian, et al. (1979), their two-dimensional, zonally averaged model was used to simulate the 1972 solar proton event. The calculations were performed first using the NO production rate described by Crutzen, et al. (1975) and then a modification of these rates to account for a 2.5 molecule/ion pair factor as determined by the measurements of Arnold (1978). Figure 25a shows their results at 70^o to 80^oN and Fig. 25b at 50^o to 60^oN. With the chemistry used in their model, the results indicate that the data can be matched much closer if the molecule/ion pair ratio is 2.5 as inferred using Arnold's (1978) data. Qualitatively, their results are similar to the present results; however, even with the 2.5 factor, the initial reduction in the O_3 column is about 50 percent lower. These differences are most probably due to the differences in the chemical reaction rates, since a large number of reaction rates updates are included in the present simulation. In addition, the latitudinal input of NO was not described in their paper; thus, it is possible that it was not uniformly inserted as in the present model simulation.

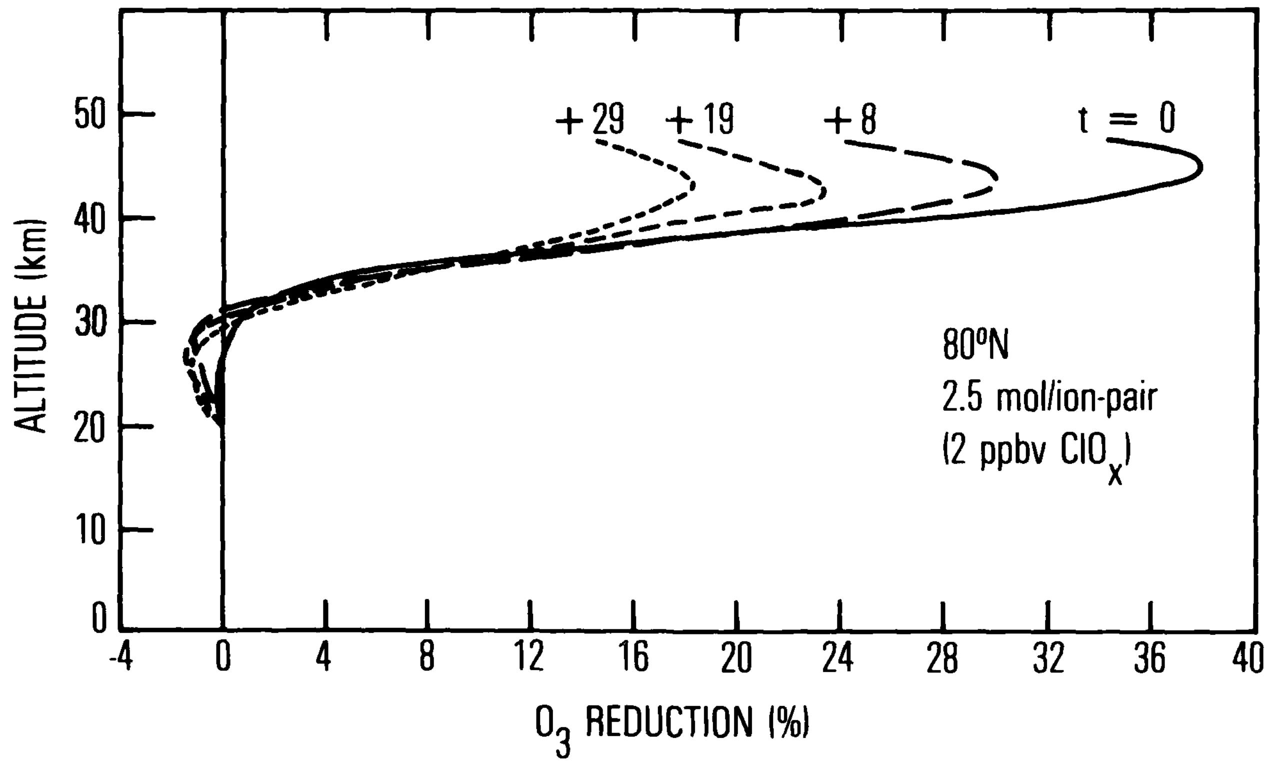


Fig. 22. Calculated Relative Reduction in Ozone Concentration with Time After Solar Proton Event (2.5 molecules/ion pair)

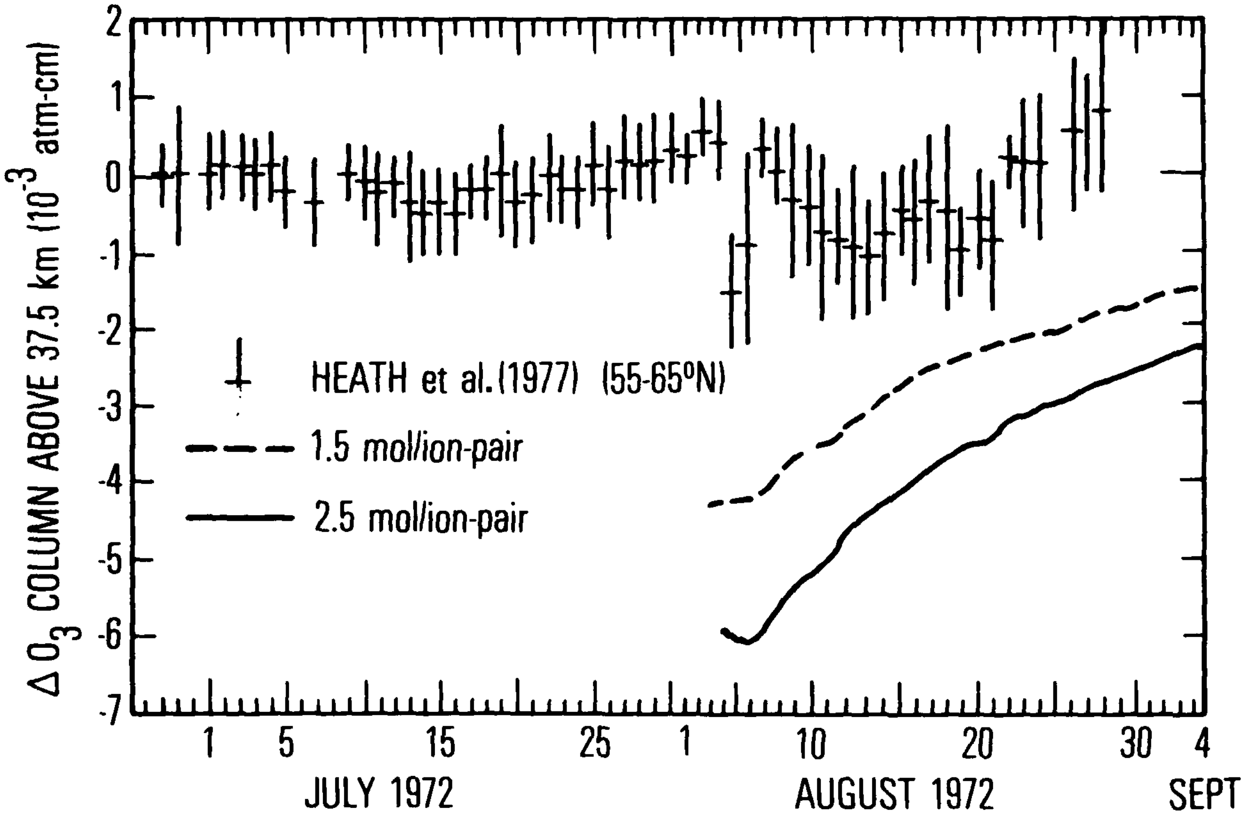
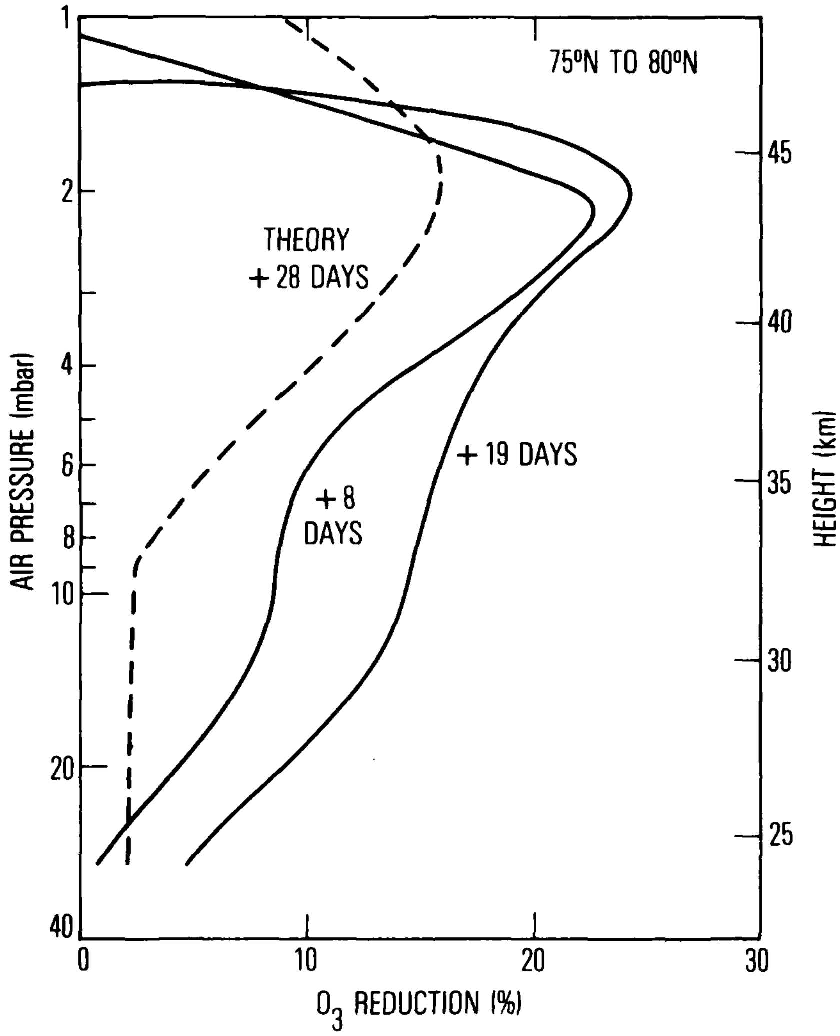
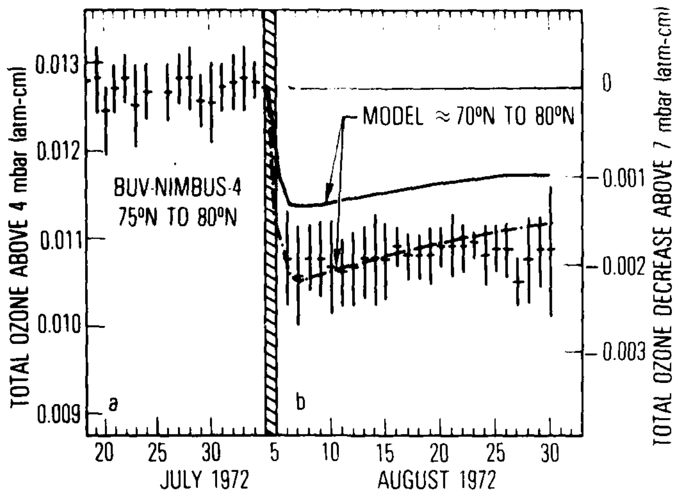


Fig. 23. Comparison of Calculated and Measured O_3 Column Change from August 1972 Solar Proton Event



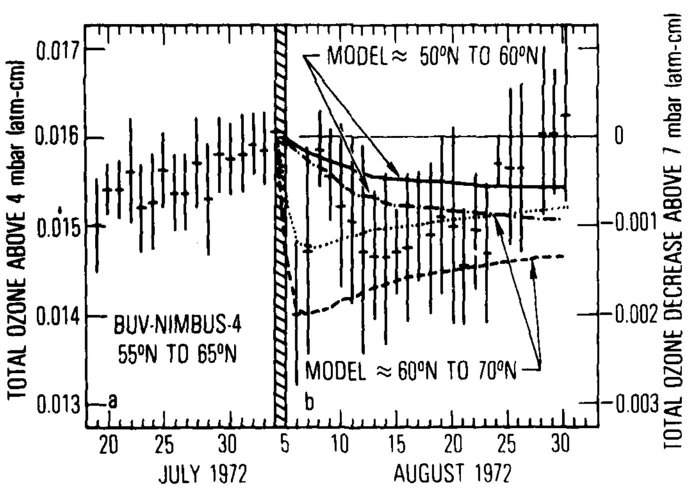
Percentage decrease of the O_3 partial pressure versus air pressure derived from the average of the 7 days before 4 August 1972 and 7-day periods centered on 8 and 19 days after the solar proton event (solid lines). (Data for 7 days before the event are used as the base line for the two solid-line curves.) The dashed line is a calculation of the O_3 reduction for 1 September 1972, due to the catalytic effect of solar proton-produced NO.

Fig. 24. O_3 Reduction as Calculated by Heath, et al. (1977) for August 1972 Solar Proton Event (After Heath, et al. (1977))



Comparison of BUV-NIMBUS-4 ozone data (a) with model prediction for high latitudes (b). The model results are plotted as relative depletions with respect to the 'undisturbed' level on 4 August, before the event occurred. The solid line bases on NO production rates as given by Crutzen, et al. The dashed line includes Arnold's modification.

(a)



Comparison of BUV-NIMBUS-4 ozone data (a) with model prediction for midlatitudes (b). The 55 to 65°N latitude range of the BUV data is somewhat between the latitude belts 50 to 60°N and 60 to 70° of the model. The solid line and the pointed line correspond to NO production rates given by Crutzen, et al., for the two latitude belts, respectively. The dashed lines include Arnold's modification. (After Fabian, et al. (1977))

(b)

Fig. 25. Comparison of BUV-NIMBUS-4 Ozone Data with Model Prediction by Fabian, et al. (1979)

In a recent paper by Jackman, et al. (1979), an upper bound on the NO molecule/ion pair ratio was estimated to be about 1.2-1.3, which more closely corresponds to the NO production determined by Crutzen. However, they indicated the value 2.5 may be appropriate above 80 km. Since the peak ozone reduction occurs below 60 km, the factor 1.5 is considered more appropriate for estimating the production of NO produced by this solar proton event.

As an additional calculation, it was decided to investigate the sensitivity of the ozone loss to the presence of ClO_x. Since the original calculations of the natural atmosphere included 2 ppbv ClO_x, we removed all the ClO_x in the natural atmosphere and ran the calculation until the non-ClO_x natural atmosphere became essentially periodic. Then, using the NO input as obtained by Crutzen (1.5 factor), the solar proton event was simulated. Figure 26 shows the resultant distribution of O_3 reduction at 80^oN. By comparing Figs. 21 and 26, we can see that the removal of ClO_x only increases the peak ozone reduction by about 2 percent after 29 days.

Before any quantitative conclusions can be drawn in regard to the validity of the model results, it must be pointed out that these calculations are preliminary, and a more accurate test of the model requires the proper latitudinal distribution of the production of NO north of 60^o. Finally, in a recent communication with Stolarski (1980), it was pointed out that the Nimbus 4 data was not properly reduced and is presently being reworked. However, some of the preliminary results indicate that the ozone recovery is qualitatively similar to the present model results. More extensive model tests will be performed once these data are available.

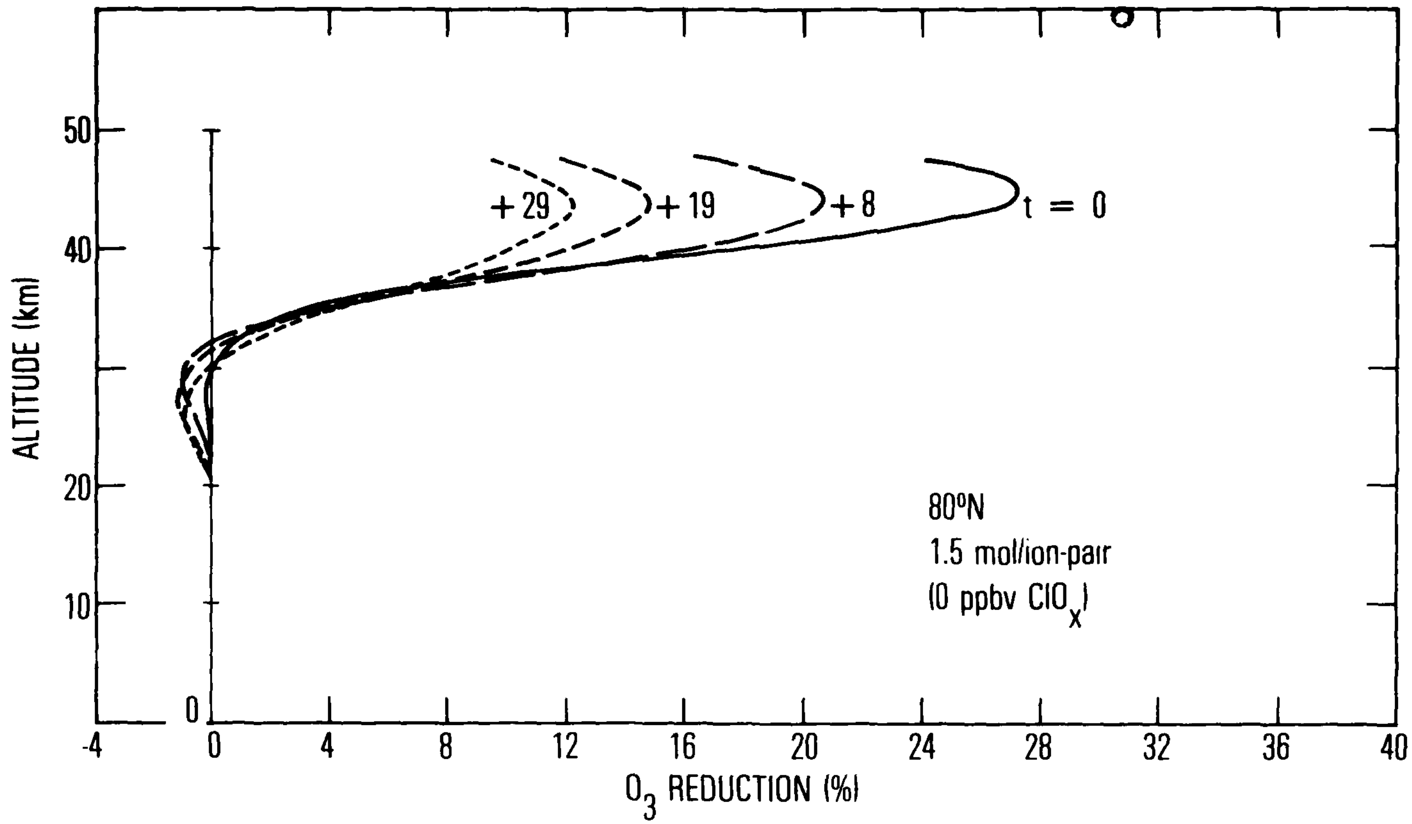


Fig. 26. Comparison of Calculated and Measured O_3 Column Change from August 1972 Solar Proton Event (no ClO_x)

PART II

MODEL RESULTS USING REACTION RATES
RECOMMENDED IN 1982

11. NATURAL ATMOSPHERE

The model described in Part I of this report was used to calculate the distribution of trace species in the natural atmosphere using a more recent recommendation of pertinent atmospheric reaction rates by the NASA Panel for Data Evaluation (NASA 1982). The specific chemical system and reaction rates used in this part of the study are listed in Table III.

As in previous simulations the variation of the chemical structure of the atmosphere was calculated for the entire yearly solar cycle until the ozone calculated at each latitude differed by no more than 0.1 percent from one year to the next throughout an entire year. The calculation was performed assuming that the level of ClO_x in the stratosphere was 2 ppbv using the same reasoning and procedure outlined in Section 8. Pertinent comparisons with measurements of trace species are presented in this section.

Model results for the monthly variation of the total ozone column as a function of latitude are shown in Figure 27 together with the data compilation of observed ozone columns (Dutsch (1971)). The agreement is reasonable, especially at the low and mid latitudes. At the higher latitudes the calculated ozone columns are higher than observed during Autumn in the northern hemisphere and during Winter and Spring in the southern hemisphere. It should be noted that these ozone column levels are much higher than computed (for the same 2 ppbv ClO_x case) using the rates recommended in 1979 (see Figure 1b).

The variation of ozone concentration with altitude was compared to available measurements. The agreement between the calculated and observed distributions of ozone with altitude at various latitudes throughout the year is good; in general similar to that computed in earlier studies (see Figure 2a-d (the Widhopf, et al (1977) curves)) and, thus, have not been repeated here. A comparison of a calculated and measured ozone profile during June at 30°N is shown in Figure 28.

The level of 2 ppbv of ClO_x was chosen in order to provide an initial estimate of the effect of ClO_x on the chemical structure of the atmosphere

Table III. Chemical Reactions and Rate Coefficients (circa 1982)

	REACTION	RATE CONSTANT* **		REACTION	RATE CONSTANT* **
1.	$O(^3P) + O_3 \rightarrow 2O_2$	$1.5\times10^{-11}\,e^{-2218/T}$	29.	$N + NO_2 \longrightarrow NO + NO$	0.
2.	$O_2 + h\nu \longrightarrow 2O(^3P)$	J_2	30.	$N_2 + O(^1D) \xrightarrow{M} N_2O$	$3.5\times10^{-37}\,(300/T)^{0.50}$
3.	$O_3 + h\nu \longrightarrow O_2 + O(^3P)$	J_3	31.	$NO_2 + N \longrightarrow N_2O + O(^3P)$	1.4×10^{-12}
4.	$NO_2 + h\nu \longrightarrow NO + O(^3P)$	J_4	32.	$O(^1D) + H_2O \longrightarrow 2OH$	2.2×10^{-10} @ 298°K
5.	$O(^3P) + O_2 \xrightarrow{M} O_3$	$6.0\times10^{-34}(300/T)^{2.3}$	33.	$O(^1D) + CH_4 \longrightarrow OH + CH_3$	1.4×10^{-10}
6.	$O(^3P) + NO_2 \rightarrow O_2 + NO$	9.3×10^{-12}	34.	$OH + O(^3P) \longrightarrow O_2 + H$	$2.2\times10^{-11}\,e^{117/T}$
7.	$O_3 + NO \longrightarrow O_2 + NO_2$	$2.2\times10^{-12}\,e^{-1430/T}$	35.	$H + O_2 \xrightarrow{M} HO_2$	$5.5\times10^{-32}\,(300/T)^{1.4}$
8.	$O_3 + NO_2 \longrightarrow O_2 + NO_3$	$1.2\times10^{-13}\,e^{-2450/T}$	36.	$H + O_3 \longrightarrow OH + O_2$	$1.4\times10^{-10}\,e^{-470/T}$
9.	$O_3 + OH \longrightarrow O_2 + HO_2$	$1.6\times10^{-12}\,e^{-940/T}$	37.	$NO + O(^3P) \xrightarrow{M} NO_2$	$k_o = 1.2\times10^{-31}\,(300/T)^{1.8}$, $k_\infty = 3\times10^{-11}\,(300/T)^{0.0}$
10.	$NO + HO_2 \longrightarrow OH + NO_2$	$3.7\times10^{-12}\,e^{+240/T}$	38.	$2OH \longrightarrow H_2O + O(^3P)$	$4.2\times10^{-12}\,e^{-242/T}$
11.	....	0.	39.	$N + O_3 \longrightarrow NO + O_2$	0.
12.	$OH + NO_2 \xrightarrow{M} HNO_3$	$k_0 = 2.6\times10^{-30}\,(300/T)^{2.9}$, $k_\infty = 2.4\times10^{-11}\,(300/T)^{1.3}$	40.	$HO_2 + h\nu \longrightarrow OH + O(^3P)$	J_{40}
13.	$HNO_3 + h\nu \longrightarrow OH + NO_2$	J_{13}	41.	$OH + CH_4 \longrightarrow H_2O + CH_3$	$2.4\times10^{-12}\,e^{-1710/T}$
14.	$HO_2 + O_3 \longrightarrow OH + O_2 + O_2$	$1.1\times10^{-14}\,e^{-580/T}$	42.	$2OH \xrightarrow{M} H_2O_2$	$k_o = 6.9\times10^{-31}\,(300/T)^{1.0}$, $k_\infty = 1.0\times10^{-11}(300/T)$
15.	$HO_2 + O(^3P) \longrightarrow OH + O_2$	$3.0\times10^{-11}\,e^{+200/T}$	43.	$H_2O_2 + O(^3P) \longrightarrow OH + HO_2$	$1.0\times10^{-11}\,e^{-2500/T}$
16.	$OH + HO_2 \longrightarrow H_2O + O_2$	$(7 + 4\,P_{atm})10^{-11}$	44.	$CO + OH \longrightarrow H + CO_2$	$1.35\times10^{-13}\,(1 + P_{atm})$
17.	$OH + HNO_3 \longrightarrow H_2O + NO_3$	$9.4\times10^{-15}\,e^{+778/T}$	45.	$CH_2O + h\nu \longrightarrow H_2 + CO$	J_{45}
18.	$H_2O_2 + h\nu \longrightarrow 2OH$	J_{18}	46.	$CHO + O_2 \longrightarrow CO + HO_2$	$3.5\times10^{-12}\,e^{140/T}$
19.	$H_2O_2 + OH \longrightarrow H_2O + HO_2$	$3.1\times10^{-12}\,e^{-187/T}$	47.	$NO_3 + NO_2 \xrightarrow{M} N_2O_5$	$k_o = 2.2\times10^{-30}\,(300/T)^{2.8}$, $k_\infty = 1.0\times10^{-12}(300/T)^{0.0}$
20.	$HO_2 + HO_2 \longrightarrow H_2O_2 + O_2$	$(3.4 + 2.5\,P_{atm})10^{-14}\,e^{+1150/T}$	48.	$N_2O_5 \xrightarrow{M} NO_3 + NO_2$	$D(4+6F)/\left[(1+6F)(4+F)\right]^{\dagger}$
21.	$O_3 + h\nu \longrightarrow O_2 + O(^1D)$	J_{21}	49.	$NO_3 + h\nu \longrightarrow 2/3(NO_2 + O) + 1/3(NO + O_2)$	J_{49}
22.	$O(^1D) \xrightarrow{M} O(^3P)$	$2.2\times10^{-11}\,e^{92/T}$	50.	$N_2O_5 + h\nu \longrightarrow NO_2 + NO_3$	J_{50}
23.	$N_2O + h\nu \longrightarrow N_2 + O(^1D)$	J_{23}	51.	$NO_3 + NO \longrightarrow 2NO_2$	2×10^{-11}
24.	$N_2O + O(^1D) \longrightarrow N_2 + O_2$	4.9×10^{-11}	52.	$NO_2 + O(^3P) \xrightarrow{M} NO_3$	$k_o = 9\times10^{-32}\,(300/T)^2$, $k_\infty = 2.2\times10^{-11}$
25.	$N_2O + O(^1D) \longrightarrow 2NO$	6.7×10^{-11}	53.	$CO_2 + h\nu \longrightarrow CO + O(^3P)$	J_{53}
26.	$NO + h\nu \longrightarrow N + O(^3P)$	J_{26}	54.	$H_2 + O(^1D) \longrightarrow OH + H$	1.0×10^{-10}
27.	$N + O_2 \longrightarrow NO + O(^3P)$	$4.4\times10^{-12}\,e^{-3220/T}$	55.	$O(^1D) + CH_4 \longrightarrow CH_2O + H_2$	1.4×10^{-11}
28.	$N + NO \longrightarrow N_2 + O(^3P)$	3.4×10^{-11}	56.	$O(^3P) + CH_4 \longrightarrow CH_3 + OH$	$3.5\times10^{-11}\,e^{-4450/T}$

*Units in sec^{-1}, cm^3sec^{-1} and cm^6sec^{-1} for unimolecular, bimolecular and trimolecular reactions.

** $k = \left[k_o[M]/(1 + k_o[M]/k_\infty)\right][0.6]^{1/\delta}$

$\delta = 1 + \left[\log\left[k_o[M]/k_\infty\right]\right]^2$

† $D = 2.2\times10^{-5}\,e^{-9700/T}$

$E = 5.7\times10^{14}\,e^{-10600/T}$

$F = D[M]/E$

Table III. Chemical Reactions and Rate Coefficients (circa 1982) (Continued)

	REACTION	REACTION RATE*,**		REACTION	REACTION RATE*,**
57.	$Cl + O_3 \longrightarrow ClO + O_2$	$2.8\times10^{-11}\ e^{-257/T}$	R_1	$CH_3O_2H + h\nu \longrightarrow CH_3O + OH$	J_{R_1}
58.	$ClO + O(^3P) \longrightarrow Cl + O_2$	$7.7\times10^{-11}\ e^{-130/T}$	R_2	$CH_3O_2 + NO \longrightarrow CH_3O + NO_2$	$4\times10^{-12}\ e^{180/T}$
59.	$ClO + NO \longrightarrow Cl + NO_2$	$6.2\times10^{-12}\ e^{294/T}$	R_3	$CH_3O_2 + HO_2 \longrightarrow CH_3O_2H + O_2$	$7.7\times10^{-14}\ e^{1300/T}$
60.	$CH_4 + Cl \longrightarrow HCl + CH_3$	$9.6\times10^{-12}\ e^{-1350/T}$	R_4	$CH_2O + h\nu \longrightarrow H_2 + CO$	J_{R_4}
61.	$Cl + H_2 \longrightarrow HCl + H$	$3.7\times10^{-11}\ e^{-2300/T}$	R_5	$CH_2O + h\nu \longrightarrow H + CHO$	J_{R_5}
62.	$HO_2 + Cl \longrightarrow HCl + O_2$	$1.8\times10^{-11}\ e^{+170/T}$	R_6	$CH_2O + OH \longrightarrow CHO + H_2O$	1×10^{-11}
63.	$OH + HCl \longrightarrow H_2O + Cl$	$2.8\times10^{-12}\ e^{-425/T}$	R_7	$CH_3O_2H + OH \longrightarrow CH_3O_2 + H_2O$	$2.6\times10^{-12}\ e^{-190/T}$
64.	$HCl + O(^3P) \longrightarrow Cl + OH$	$1.0\times10^{-11}\ e^{-3340/T}$	R_8	$CH_2O + O(^3P) \longrightarrow CHO + OH$	$3.0\times10^{-11}\ e^{-1550/T}$
65.	$Cl + OH \longrightarrow HCl + O(^3P)$	$1\times10^{-11}\ e^{-2970/T}$	R_9	$CH_3 + O_2 \xrightarrow{M} CH_3O_2$	$k_o = 2.2\times10^{-31}\ (300/T)^{2.2},\ k_\infty = 2\times10^{-12}\ (300/T)^{1.7}$
66.	$ClO + h\nu \longrightarrow Cl + O(^3P)$	J_{66}	R_{10}	$CH_3O + O_2 \longrightarrow CH_2O + HO_2$	$1.2\times10^{-13}\ e^{-1350/T}$
67.	$HCl + h\nu \longrightarrow H + Cl$	J_{67}			
68.	$ClO + NO_2 + N_2 \longrightarrow ClONO_2 + N_2$	$k_o = 4.5\times10^{-32}\ (300/T)^{3.8},\ k_\infty = 1.5\times10^{-11}\ (300/T)^{1.9}$			
69.	$ClONO_2 + h\nu \longrightarrow ClO + NO_2$	J_{69}			
70.	$ClONO_2 + Cl \longrightarrow$ Products	$6\times10^{-12}\ e^{+150/T}$			
71.	$ClONO_2 + OH \longrightarrow$ Products	$1.2\times10^{-12}\ e^{+333/T}$			
72.	$ClONO_2 + O(^3P) \longrightarrow ClO + NO_3$	$3\times10^{-12}\ e^{-808/T}$			
73.	$ClO + ClO \longrightarrow ClO + Cl + O(^3P)$	$2.1\times10^{-12}\ e^{-2200/T}$			
74.	$ClO + ClO \longrightarrow 2Cl + O_2$	$1.5\times10^{-12}\ e^{-1238/T}$			
75.	$HO_2 + NO_2 \xrightarrow{M} HO_2NO_2$	$k_o = 2.3\times10^{-31}\ (300/T)^{4.6};\ k_\infty = 4.2\times10^{-12}\ (300/T)^{0.0}$			
76.	$HO_2NO_2 + Cl \longrightarrow HCl + NO_2 + O_2$	0.			
77.	$HO_2NO_2 + O(^3P) \longrightarrow OH + NO_2 + O_2$	$7\times10^{-11}\ e^{-3370/T}$			
78.	$HO_2NO_2 + OH \longrightarrow H_2O + NO_2 + O_2$	$1.3\times10^{-12}\ e^{+380/T}$			
79.	$HO_2NO_2 + h\nu \longrightarrow HO_2 + NO_2$	J_{79}			
80.	$Cl + H_2O_2 \longrightarrow HCl + HO_2$	$1.1\times10^{-11}\ e^{-980/T}$			

*Units in sec^{-1}, $cm^3 sec^{-1}$ and $cm^6 sec^{-1}$ for unimolecular, bimolecular and trimolecular reactions.

** $k = \{k_o[M]/(1 + k_o[M]/k_\infty)\}\,(0.6)^{1/\delta}$

$\delta = 1 + \{\log\,(k_o[M]/k_\infty)\}^2$

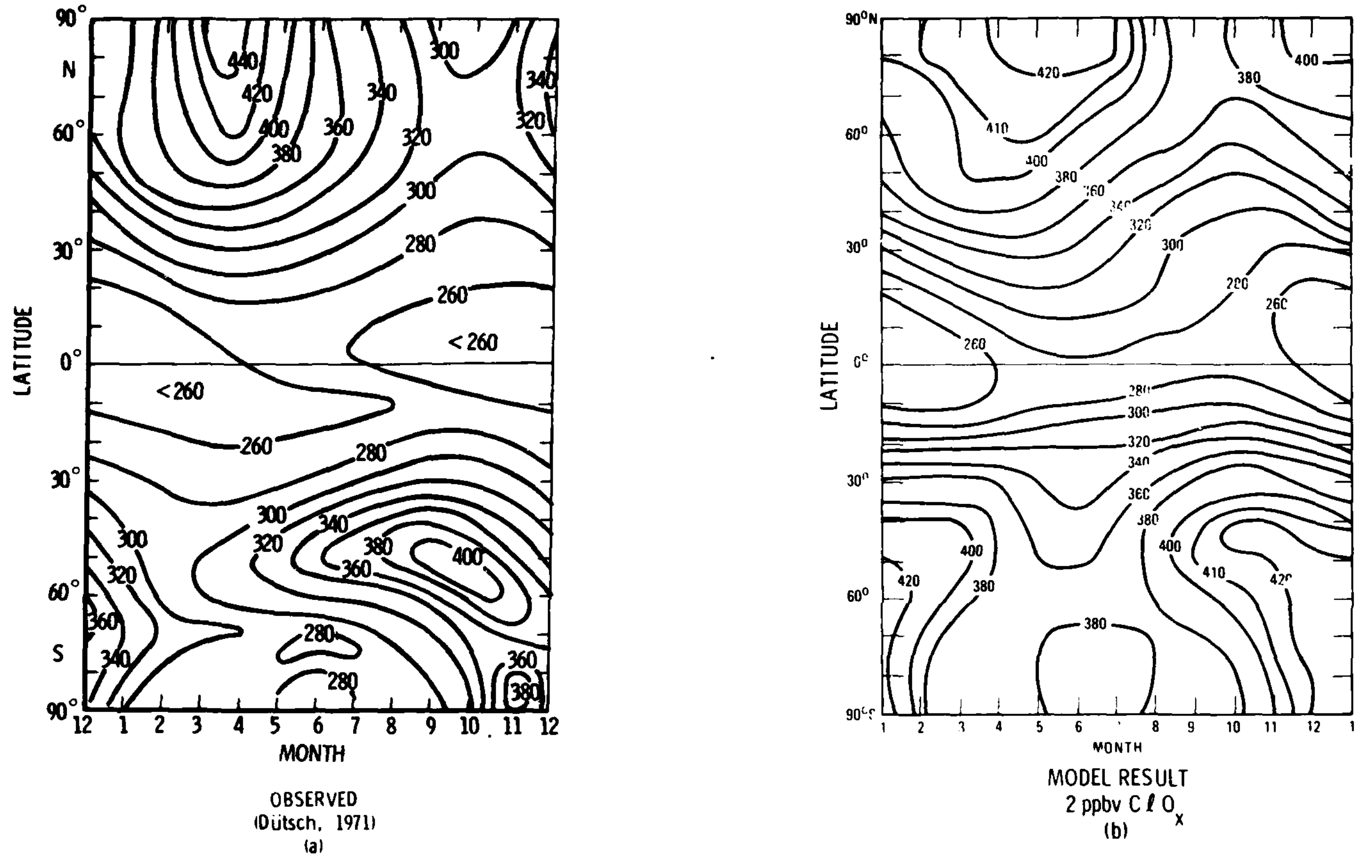


Fig. 27. Calculated and Observed Monthly Variation of the Total Ozone Column as a Function of Latitude (10^{-3} cm at STP) Using Reactions Rates Recommended in 1982

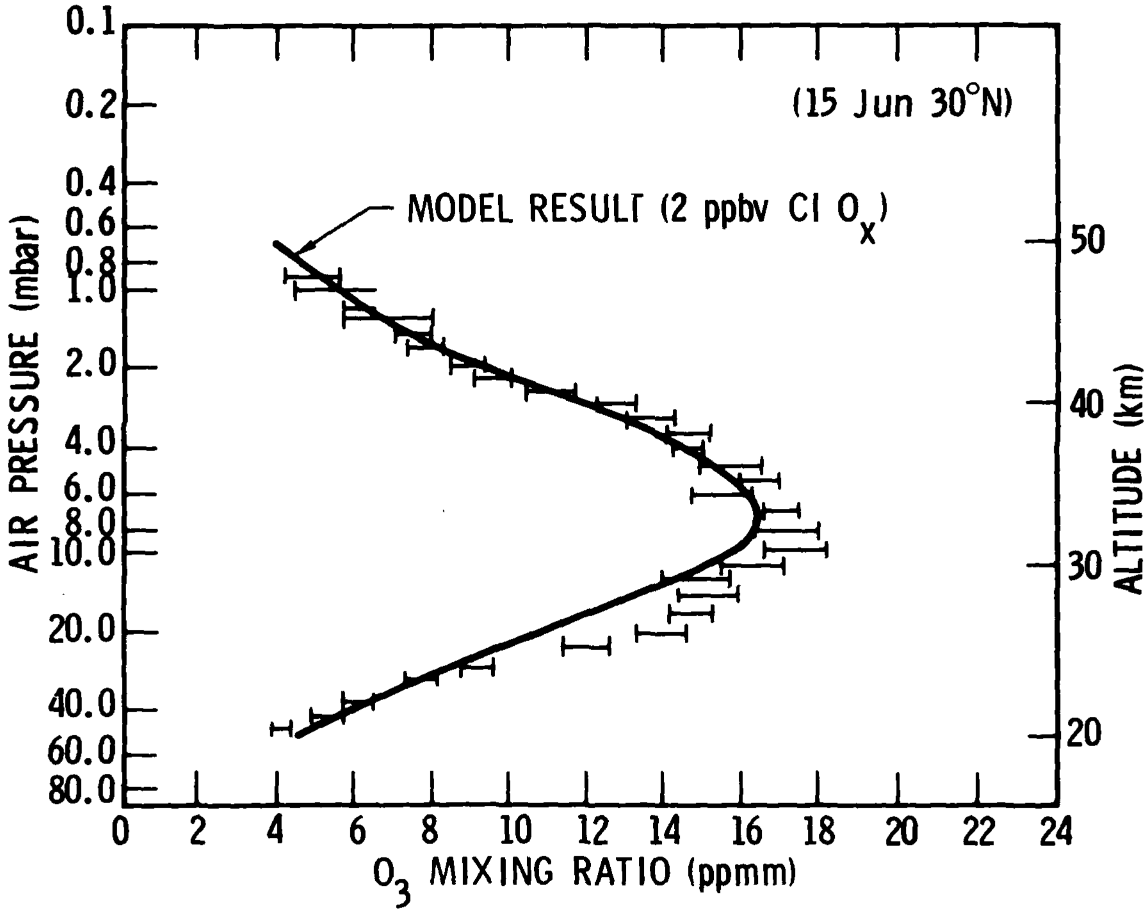


Fig. 28. Comparison of Calculated Ozone Profiles (15 June at 30°N) with Measurements

in the same manner as was done in Part I. A comparison of the calculated profiles of Cl, ClO and HCl with corresponding avilable measurements are shown in Figs 29 and 30. Because ClO_x was introduced uniformly throughout the year, the variation of the calculated Cl and ClO concentrations does not vary much ($\sim$10 percent) with time of year. Also, because ClO_x was introduced in a parametric manner, at a level estimated to be reasonable, any direct comparisons with ClO_x measurements are not strictly valid, but provide only relative comparisons. However, the profiles at 30°N, during July, are in relative agreement with measurements during July at 32°N. The calculated HCl distribution during May is shown in Fig. 30 and is in relative agreement with the measurements shown. The difference between the present distributions of these ClO_x constituents and that obtained in Part I are noticeable, but not major.

Various other comparisons between calculated and measured distributions of trace species in the atmosphere were made in a manner similar to those presented in Part I. Distributions for H_2O, tropospheric NO_x and HNO_3, N_2O and CH_4 are either very close to the distributions shown in Figs 5a-d, 6, 7, 11 and 12, respectively, or were not sufficiently different to be worth mentioning.

In Part I it was shown that the distribution of HNO_3 was overpredicted using the reaction rates included in Table I (see Figs 8 and 9). However, calculations using the updated rates in Table III are in much better agreement with distributions of NO, NO_2 and HNO_3, as well as the HNO_3 column above 12 km, than were the previous results. These comparisons are shown in Figs. 31 and 32. This is an important change in the correct direction.

In summary, the use of the updated reaction rate data recommendation yields results which are in much better agreement with observations than was the case for the 1979 chemical set given in Table I. This is especially true for the O_3 and HNO_3 columns as well as the distributions of NO, NO_2 and HNO_3.

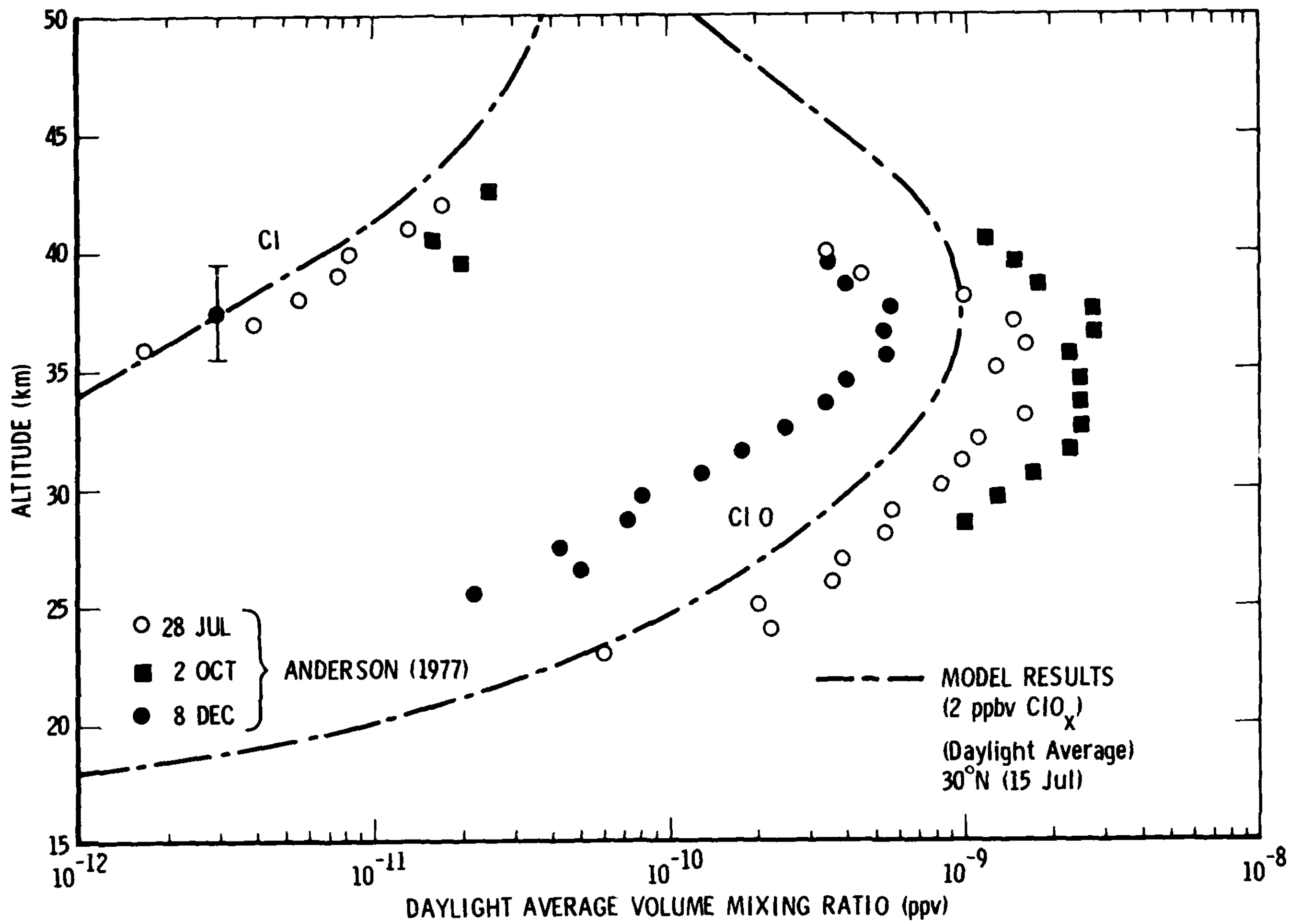


Fig. 29. Comparison of Calculated and Observed Cl and ClO Profiles

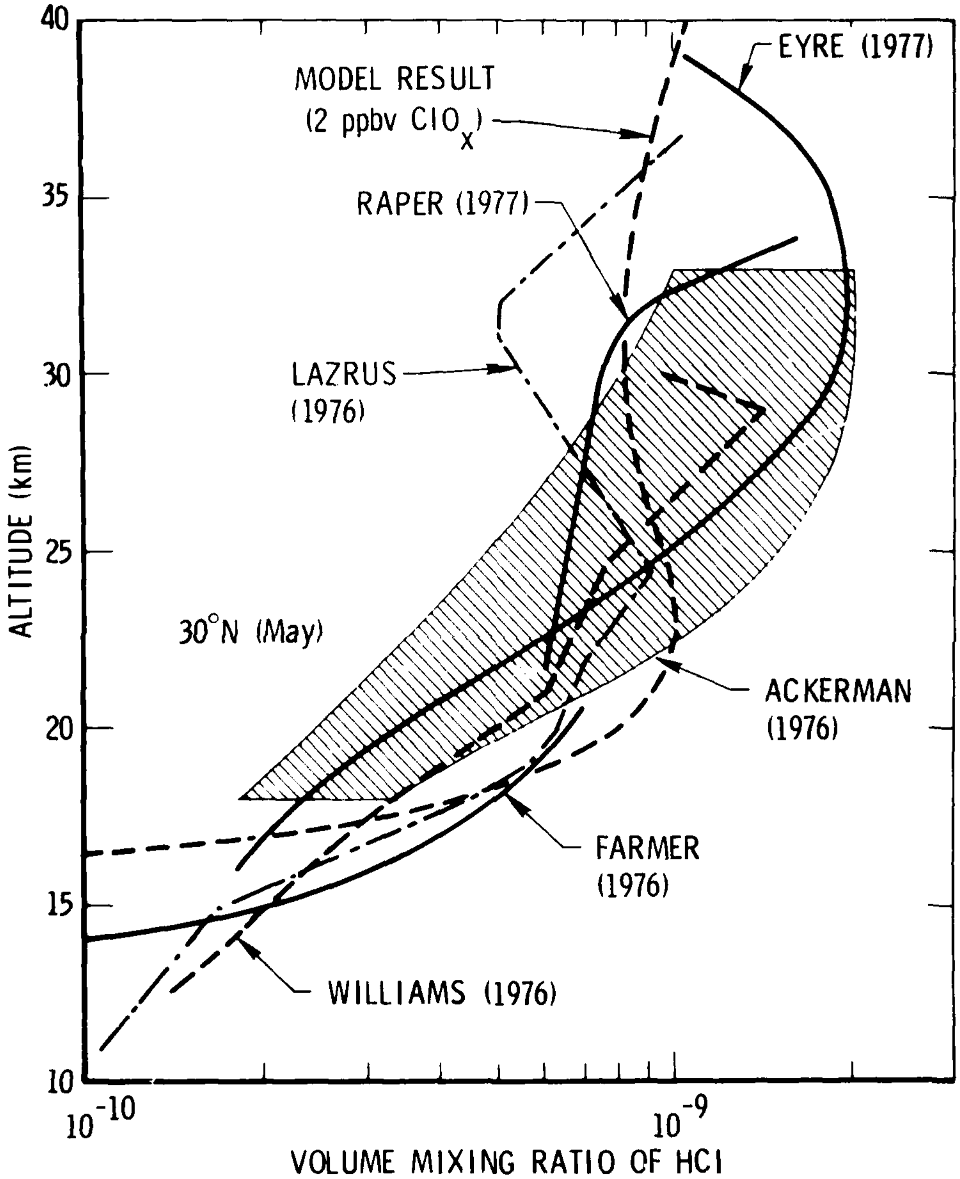


Fig. 30. Comparison of Calculated and Measured Distribution of HCl

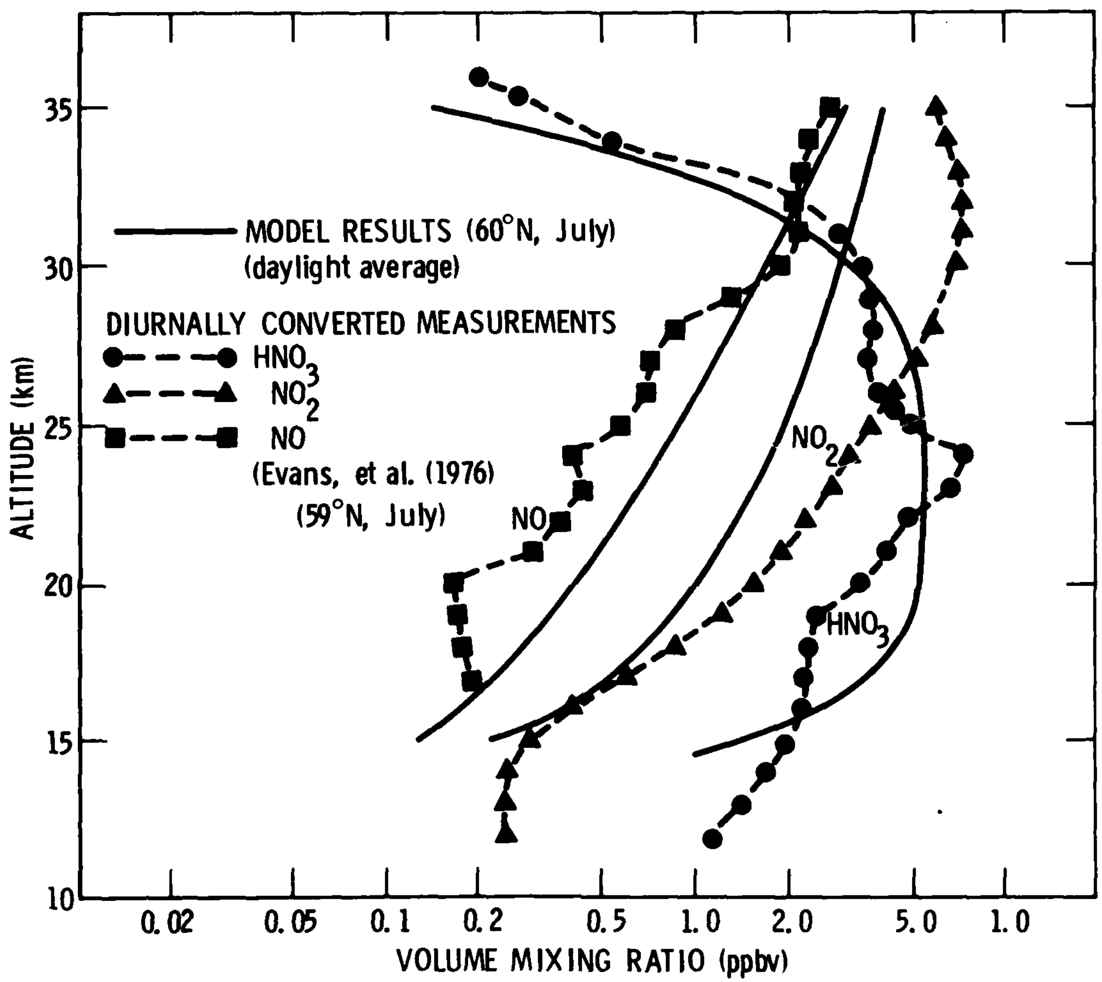


Fig. 31. Comparison of Calculated and Measured Profiles of NO, NO_2 and HNO_3

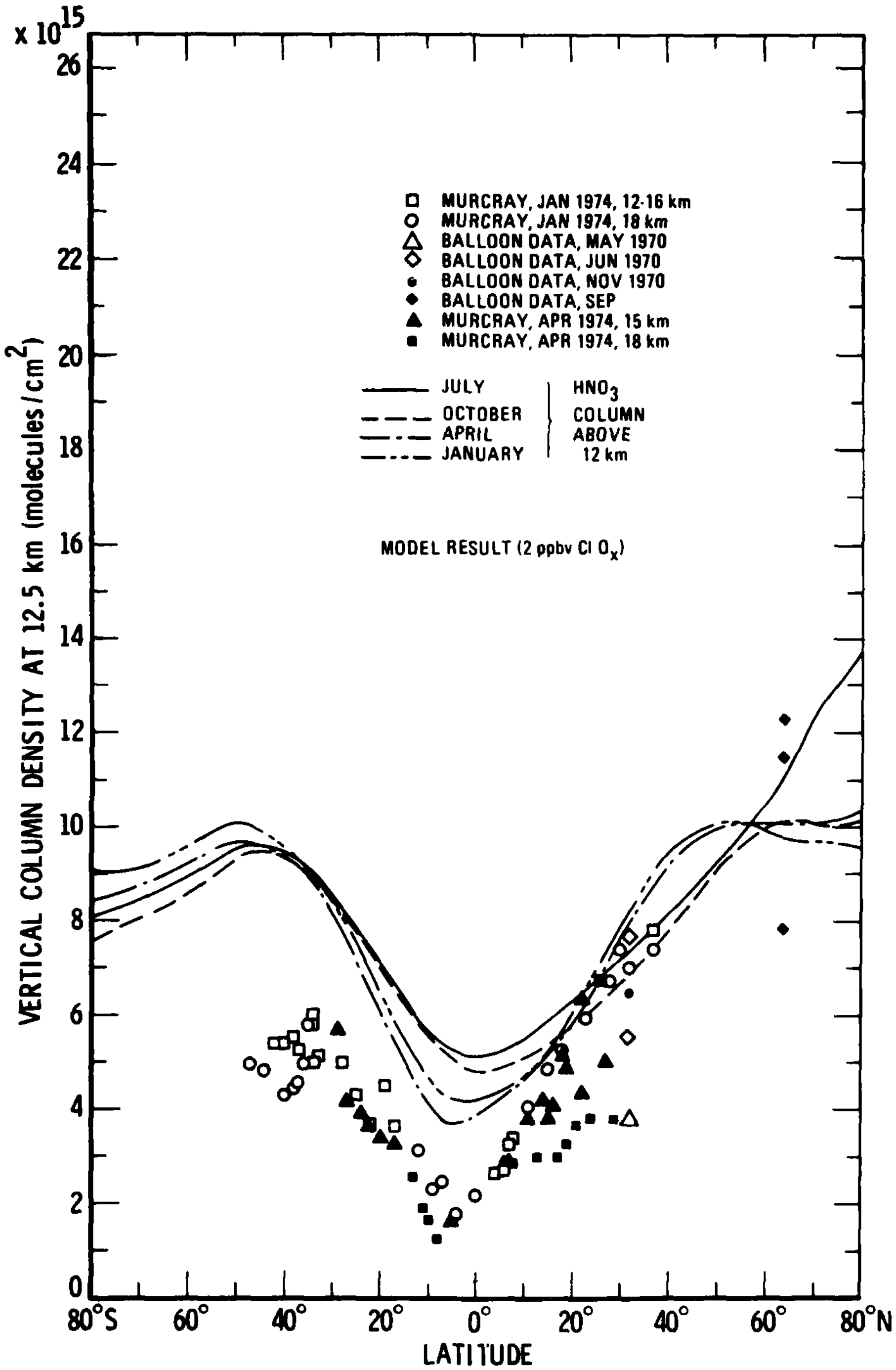


Fig. 32. Comparison of Calculated and Observed HNO_3 Column Variation with Latitude

12. AIRCRAFT EMISSIONS EFFECTS

Emissions from a fleet of subsonic and supersonic aircraft (see Table II) projected to be operational in 1990 (Little (1976); Oliver (1976)) were introduced into the simulated 1990 natural atmosphere described in the previous Section. The emission levels are the same as used in previous investigations using this atmospheric model. Only NO_x emissions were introduced since results described in Part I demonstrated that H_2O emissions have a negligible effect on ozone. This is because the level of injected H_2O is very low compared to the natural atmospheric background at corresponding altitudes. The simulation was carried out for a four year period after the yearly variation in total ozone column in the natural atmosphere changed by less than 0.1% from year to year. For the present simulation the emissions were introduced continuously starting in October.

The effect of these emissions on the ozone layer is summarized in Fig. 33 which shows the total ozone column change at various latitudes over a four-year period of continuous aircraft fleet operation. A small increase in ozone column occurs at all latitudes depicted and also at all other latitudes not shown. Based on previous experience with the model and a desire to reduce computational costs, it was determined that a four-year simulation was sufficient.

The latitudinal distributions of these resultant changes in total ozone column during October, July, April, and January of the fifth year of simulation are shown in Fig. 34. Shown in the insert is the total amount of NO_2 injected at each latitude. Note that the peak ozone change ($\sim$3.1 percent) occurs at 30 to 40°N in October (corresponding to the latitudes for peak injection) and moves slightly southward, peaking about 30°N during April. This transport effect is similar to that observed in previous calculations reported in Part I. Thus, the present simulations also show a definite corridor effect as was present in previous estimates of NO_x pollution effects (see Section 9). The effect in the southern hemisphere is

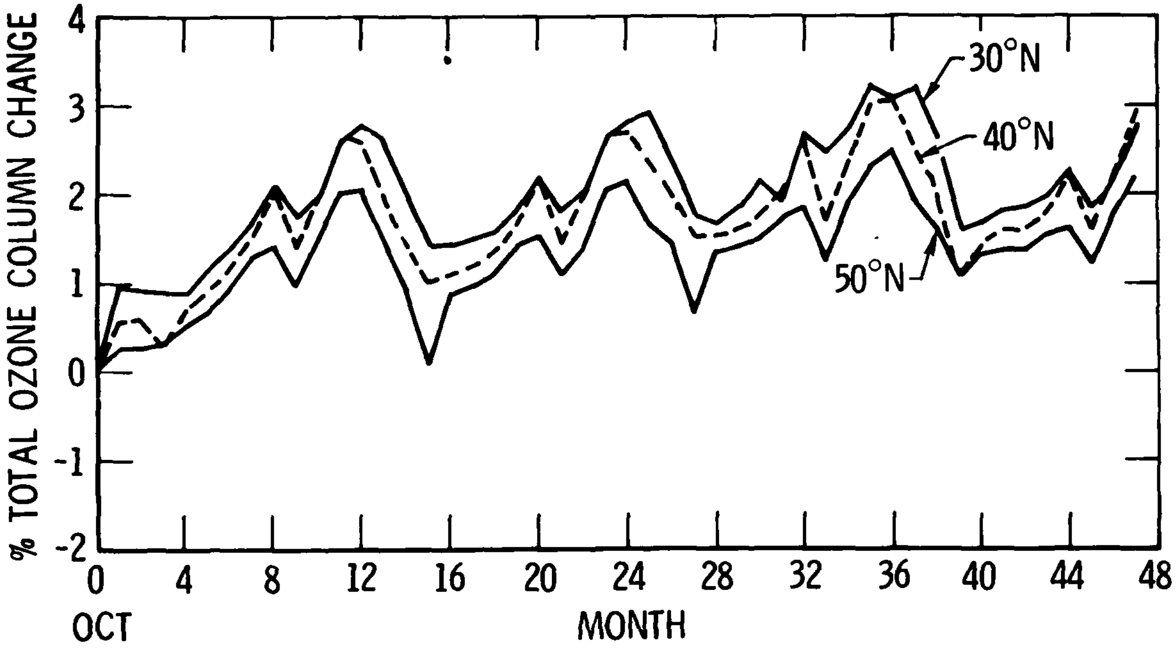


Fig. 33. Calculated Temporal Ozone Column Change Resulting from NO_x Emissions from a Combined Subsonic and Supersonic Fleet of Aircraft (Table II)

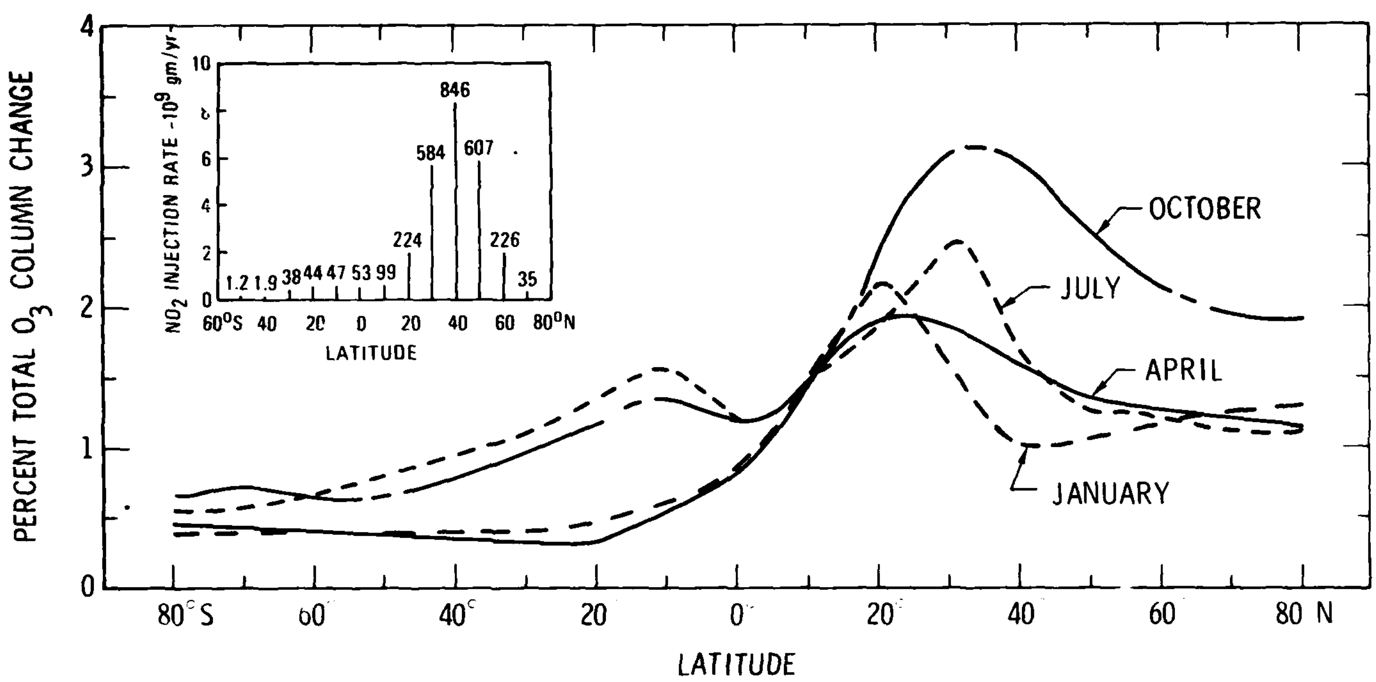


Fig. 34. Calculated Monthly Variation of the Total Zone Column Change as a Function of Latitude

much smaller than the perturbation in the northern hemisphere as a result of the injection scenario used in these calculations. However, interhemispheric transport has resulted in an average level of change, approximatedly 0.5 to 0.75 percent in the ozone column in the southern hemisphere where the primary change in the southern hemisphere occurs at low latitudes.

The overall change in ozone column in the southern hemisphere is generally the same level as obtained in the previous simulation described in Section 9. In the northern hemisphere the magnitude is, on the average, approximately 75 percent of the previous simulation.

Shown in Fig 35 are the variation in ozone column change with altitude at 20°, 30°, 40° and 50°N latitude during the months of October, January, April and July of the fourth year of aircraft operations. The distributions are quite similar to that obtained in Part I, with the aforementioned reduction in magnitude. The more recent calculations show a higher level above 20 km, however, because of the small magnitude of the ozone change, this is not believed to be very significant.

The monthly variation of the northern and southern hemispheric total ozone column changes are depicted during the fourth year of operations in Fig. 36, together with the corresponding globally average variation. The yearly averaged change in the southern hemisphere is one-third of the change which occurs in the northern hemisphere (1.75 percent), where the predominant contribution occurs between 0° and 30°S. Averaged over the entire year the global average is approximately 1.15 percent.

Previous calculations performed using this model with the same NO_x emissions distribution [Widhopf, et al (1977)], predicted that ozone was produced as a result of NO_x emissions emitted from subsonic aircraft flying below approximately 13 km. In Part I small amounts of ozone were also found to be produced by the emissions from higher flying aircraft. The same type of result reported in Part I is found in this most recent study. A discussion of the pertinent chemical mechanisms is included in the cited references and not repeated here, since there have not been any significant changes with these results.

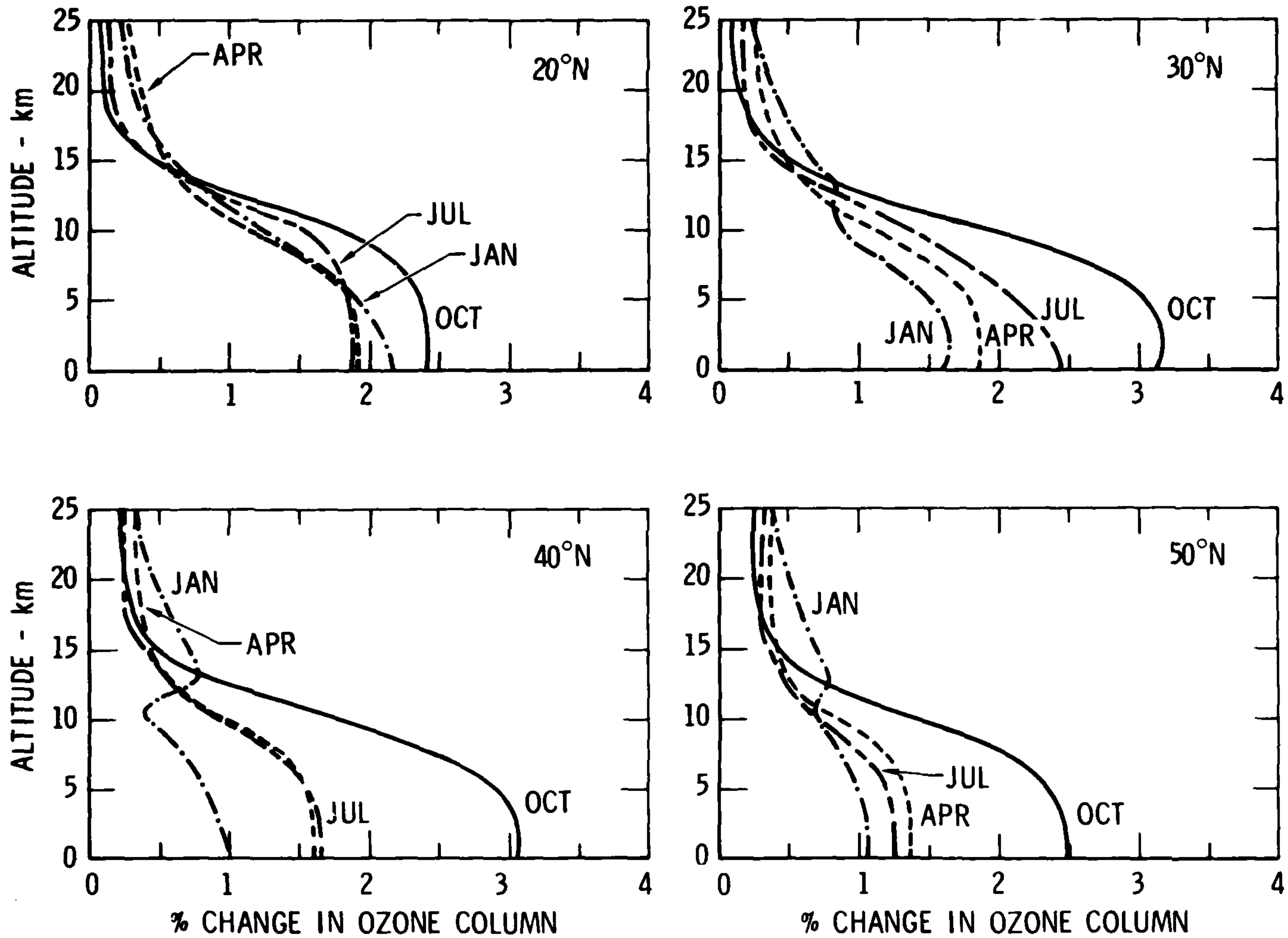


Fig. 35. O_3 Column Change as a Function of Altitude

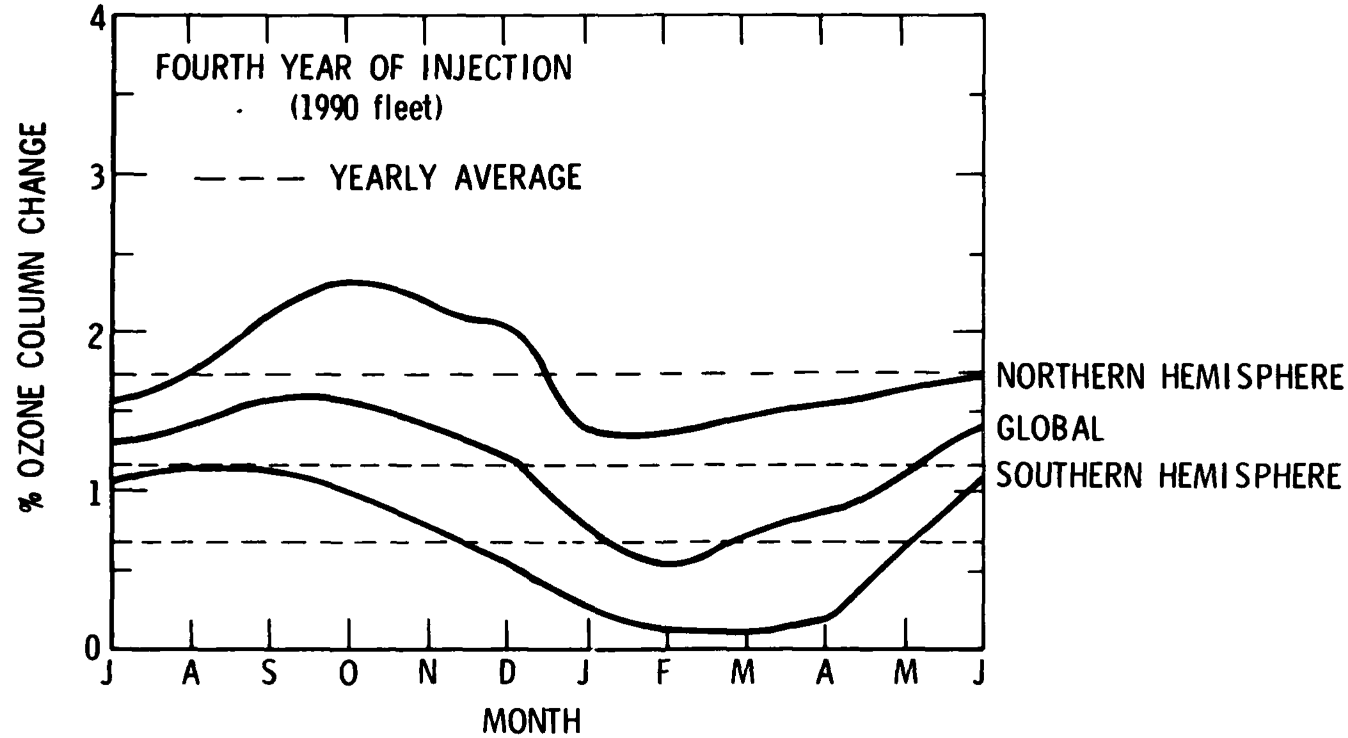


Fig. 36. Monthly Variation of Northern and Southern Hemispheric and Globally Averaged Total O_3 Column Changes

It should again be emphasized that for different aircraft fleets, depending on the fleet size and the specific cruising altitudes, the relative magnitude of the effects of NO_x emissions can be different than found for this fleet. It should also be emphasized that these estimates are dependent upon our present capability to model all the important mechanisms controlling this phenomenon, which are modelled rather than computed from first principles. Our present state of knowledge is some of these areas is deficient and future improvements may change these results.

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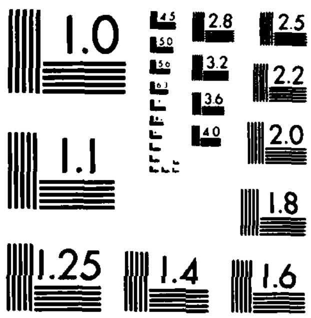
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APPENDIX

HYDRODYNAMIC AND TRANSPORT PARAMETERS

Listed in this Appendix are the meridional distributions of T, k_{zz}, $k_{\phi z}$, $k_{\phi\phi}$, v, and w for 15 October, 15 January, 15 April, and 15 July as used in the calculations described in this report.

T (IN UNITS OF 100. DEGREES KELVIN)   FOR   OCTOBER

	SOUTH						LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	2.785	2.735	2.691	2.674	2.673	2.680	2.691	2.705	2.718	2.728	2.723	2.708	2.678	2.643	2.618	2.598	2.588
47.5	2.799	2.755	2.706	2.683	2.679	2.677	2.677	2.687	2.703	2.703	2.694	2.678	2.653	2.611	2.578	2.553	2.547
45.0	2.754	2.721	2.674	2.644	2.636	2.638	2.643	2.653	2.665	2.663	2.652	2.637	2.609	2.563	2.524	2.499	2.496
42.5	2.685	2.657	2.616	2.586	2.580	2.584	2.594	2.605	2.614	2.611	2.600	2.584	2.553	2.506	2.465	2.441	2.436
40.0	2.609	2.587	2.556	2.532	2.524	2.529	2.541	2.551	2.556	2.554	2.545	2.528	2.493	2.448	2.407	2.381	2.373
37.5	2.533	2.516	2.497	2.480	2.471	2.474	2.485	2.493	2.498	2.494	2.488	2.473	2.440	2.394	2.352	2.327	2.316
35.0	2.462	2.453	2.441	2.429	2.420	2.419	2.428	2.436	2.439	2.436	2.432	2.418	2.388	2.344	2.302	2.276	2.260
34.0	2.434	2.428	2.419	2.408	2.400	2.397	2.404	2.412	2.414	2.413	2.409	2.398	2.368	2.325	2.283	2.257	2.239
33.0	2.406	2.403	2.397	2.388	2.379	2.375	2.380	2.388	2.390	2.388	2.387	2.377	2.349	2.307	2.265	2.238	2.220
32.0	2.378	2.378	2.375	2.367	2.358	2.353	2.356	2.363	2.365	2.365	2.364	2.356	2.330	2.289	2.249	2.221	2.203
31.0	2.351	2.353	2.353	2.347	2.338	2.331	2.333	2.337	2.341	2.342	2.342	2.336	2.311	2.273	2.234	2.205	2.184
30.0	2.324	2.329	2.331	2.326	2.318	2.310	2.310	2.313	2.315	2.318	2.320	2.316	2.292	2.258	2.220	2.191	2.169
29.0	2.298	2.306	2.309	2.305	2.297	2.290	2.288	2.289	2.291	2.294	2.298	2.296	2.275	2.243	2.208	2.179	2.157
28.0	2.273	2.282	2.286	2.282	2.277	2.270	2.266	2.265	2.266	2.270	2.275	2.275	2.259	2.230	2.197	2.168	2.147
27.0	2.249	2.260	2.265	2.261	2.257	2.252	2.245	2.242	2.243	2.246	2.251	2.255	2.244	2.218	2.188	2.160	2.138
26.0	2.227	2.238	2.245	2.242	2.239	2.234	2.226	2.219	2.219	2.223	2.229	2.235	2.229	2.208	2.181	2.154	2.132
25.0	2.208	2.220	2.228	2.225	2.223	2.217	2.207	2.197	2.195	2.199	2.207	2.215	2.216	2.199	2.175	2.150	2.128
24.0	2.192	2.205	2.213	2.211	2.208	2.201	2.188	2.176	2.171	2.175	2.183	2.195	2.203	2.192	2.171	2.147	2.127
23.0	2.179	2.193	2.202	2.199	2.194	2.186	2.169	2.153	2.146	2.149	2.160	2.174	2.190	2.186	2.169	2.148	2.129
22.0	2.168	2.184	2.194	2.190	2.182	2.171	2.150	2.130	2.122	2.124	2.135	2.152	2.175	2.181	2.169	2.151	2.134
21.0	2.158	2.176	2.190	2.185	2.171	2.155	2.129	2.106	2.097	2.099	2.111	2.130	2.161	2.177	2.172	2.157	2.142
20.0	2.147	2.168	2.186	2.182	2.162	2.138	2.105	2.080	2.072	2.073	2.086	2.108	2.147	2.174	2.176	2.165	2.150
19.0	2.136	2.160	2.182	2.182	2.157	2.119	2.078	2.051	2.040	2.043	2.058	2.085	2.133	2.172	2.180	2.174	2.160
18.0	2.124	2.149	2.177	2.184	2.156	2.103	2.046	2.012	2.001	2.007	2.026	2.062	2.121	2.171	2.187	2.184	2.170
17.0	2.110	2.135	2.169	2.185	2.159	2.093	2.018	1.980	1.975	1.982	2.002	2.046	2.114	2.173	2.195	2.195	2.181
16.0	2.092	2.118	2.157	2.185	2.165	2.096	2.018	1.983	1.982	1.987	2.002	2.047	2.116	2.176	2.203	2.205	2.193
15.0	2.074	2.101	2.147	2.187	2.175	2.114	2.053	2.028	2.029	2.031	2.037	2.068	2.125	2.178	2.208	2.213	2.203
14.0	2.057	2.086	2.139	2.188	2.187	2.143	2.106	2.097	2.100	2.100	2.097	2.106	2.143	2.181	2.206	2.216	2.211
13.0	2.042	2.076	2.132	2.185	2.197	2.176	2.166	2.170	2.176	2.176	2.167	2.159	2.170	2.186	2.201	2.214	2.215
12.0	2.030	2.070	2.130	2.182	2.208	2.217	2.230	2.244	2.251	2.250	2.237	2.221	2.209	2.200	2.198	2.204	2.209
10.0	2.025	2.089	2.165	2.226	2.282	2.334	2.373	2.392	2.396	2.390	2.376	2.354	2.320	2.277	2.237	2.206	2.188
8.0	2.117	2.179	2.258	2.337	2.411	2.469	2.507	2.527	2.534	2.529	2.509	2.484	2.447	2.397	2.346	2.300	2.267
6.0	2.251	2.299	2.375	2.459	2.537	2.596	2.635	2.658	2.664	2.655	2.635	2.608	2.566	2.514	2.467	2.420	2.384
4.0	2.365	2.422	2.497	2.575	2.652	2.717	2.756	2.779	2.787	2.778	2.757	2.726	2.676	2.620	2.574	2.530	2.488
2.0	2.469	2.531	2.602	2.672	2.753	2.823	2.864	2.888	2.897	2.889	2.866	2.829	2.773	2.713	2.668	2.627	2.577
0.0	2.558	2.622	2.688	2.754	2.836	2.910	2.957	2.981	2.989	2.984	2.963	2.920	2.852	2.777	2.719	2.662	2.584

KZZ (IN UNITS OF .00001 KMSQ/SEC) FOR OCTOBER

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	NORTH 10	20	30	40	50	60	70	80
50.0	2.115	3.372	3.997	2.769	3.742	1.100	.251	.335	.287	.215	.190	.536	2.642	6.191	2.393	1.239	3.006
47.5	1.810	2.886	3.420	2.370	3.202	.941	.214	.286	.246	.184	.162	.458	2.261	5.298	2.048	1.060	2.572
45.0	1.505	2.400	2.844	1.971	2.663	.783	.178	.238	.204	.153	.135	.381	1.880	4.405	1.703	.882	2.139
42.5	1.200	1.913	2.267	1.571	2.123	.624	.142	.190	.163	.122	.108	.304	1.499	3.512	1.357	.703	1.705
40.0	.895	1.427	1.691	1.172	1.583	.465	.106	.142	.122	.091	.080	.227	1.118	2.619	1.012	.524	1.272
37.5	.763	1.216	1.441	.999	1.349	.397	.090	.121	.104	.077	.068	.193	.953	2.233	.863	.447	1.084
35.0	.630	1.005	1.191	.826	1.116	.328	.075	.100	.086	.064	.057	.160	.788	1.846	.713	.369	.896
34.0	.578	.921	1.092	.756	1.022	.300	.068	.091	.078	.059	.052	.146	.722	1.691	.654	.338	.821
33.0	.525	.837	.992	.687	.928	.273	.062	.083	.071	.053	.047	.133	.656	1.536	.594	.307	.746
32.0	.472	.752	.892	.618	.835	.245	.056	.075	.064	.048	.042	.120	.590	1.381	.534	.276	.671
31.0	.419	.668	.792	.549	.741	.218	.050	.066	.057	.043	.038	.106	.524	1.227	.474	.245	.596
30.0	.366	.584	.692	.479	.648	.190	.043	.058	.050	.037	.033	.093	.457	1.072	.414	.215	.520
29.0	.335	.534	.633	.439	.593	.174	.040	.053	.046	.034	.030	.085	.419	.981	.379	.196	.476
28.0	.304	.485	.574	.398	.538	.158	.036	.048	.041	.031	.027	.077	.380	.890	.344	.178	.432
27.0	.273	.435	.516	.357	.483	.142	.032	.043	.037	.028	.024	.069	.341	.799	.309	.160	.388
26.0	.242	.386	.457	.317	.428	.126	.029	.038	.033	.025	.022	.061	.302	.708	.274	.142	.344
25.0	.211	.336	.398	.276	.373	.110	.025	.033	.029	.021	.019	.053	.263	.617	.238	.123	.299
24.0	.180	.286	.339	.235	.318	.093	.021	.028	.024	.018	.016	.045	.224	.526	.203	.105	.255
23.0	.149	.237	.281	.195	.263	.077	.018	.024	.020	.015	.013	.038	.186	.435	.168	.087	.211
22.0	.117	.187	.222	.154	.208	.061	.014	.019	.016	.012	.011	.030	.147	.344	.133	.069	.167
21.0	.086	.138	.163	.113	.153	.045	.010	.014	.012	.009	.008	.022	.108	.253	.098	.051	.123
20.0	.055	.088	.105	.072	.098	.029	.007	.009	.008	.006	.005	.014	.069	.162	.063	.032	.079
19.0	.097	.097	.097	.083	.117	.069	.022	.013	.009	.009	.014	.034	.095	.157	.080	.080	.080
18.0	.089	.089	.089	.094	.137	.110	.038	.017	.011	.012	.023	.055	.122	.152	.098	.098	.098
17.0	.082	.082	.081	.105	.156	.150	.054	.021	.012	.015	.031	.075	.148	.147	.115	.115	.115
16.0	.080	.080	.080	.117	.172	.179	.067	.025	.014	.018	.040	.092	.172	.147	.129	.129	.129
15.0	.102	.102	.102	.133	.172	.157	.065	.031	.022	.019	.050	.088	.160	.161	.127	.127	.127
14.0	.125	.125	.125	.150	.173	.135	.063	.036	.029	.020	.060	.084	.147	.175	.125	.125	.125
13.0	.147	.147	.147	.167	.173	.112	.061	.041	.036	.021	.070	.080	.135	.189	.123	.123	.123
12.0	.165	.166	.168	.184	.173	.090	.078	.054	.048	.029	.089	.090	.122	.203	.121	.060	.058
10.0	.103	.103	.104	.136	.349	.145	.128	.095	.085	.057	.142	.144	.270	.195	.129	.089	.080
8.0	.118	.118	.119	.211	.545	.231	.209	.164	.152	.109	.227	.229	.378	.279	.153	.114	.105
6.0	.170	.220	.227	.345	.704	.369	.343	.285	.269	.210	.364	.366	.531	.424	.276	.175	.168
4.0	.347	.414	.427	.563	.908	.590	.561	.496	.477	.405	.583	.585	.748	.646	.486	.360	.347
2.0	.715	.784	.800	.919	1.168	.941	.917	.862	.846	.779	.934	.936	1.058	.984	.855	.737	.722
0.0	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500

KFZ (IN UNITS OF .001 KMSQ/SEC) FOR OCTOBER

				SOUTH				LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	.267	.606	.808	.748	.914	.355	.065	.093	.046	.005	-.021	-.324	-1.350	-1.312	-1.312	-.984	-.433
47.5	.305	.692	.923	.855	.914	.355	.065	.097	.046	.005	-.021	-.324	-1.350	-1.312	-1.312	-.984	-.433
45.0	.343	.779	1.038	.962	.997	.372	.066	.101	.046	.006	-.021	-.356	-1.538	-1.518	-1.518	-1.138	-.501
42.5	.356	.809	1.079	1.000	1.018	.329	.058	.094	.043	.005	-.017	-.329	-1.471	-1.534	-1.534	-1.150	-.506
40.0	.369	.840	1.120	1.037	1.039	.287	.051	.087	.039	.005	-.013	-.301	-1.404	-1.550	-1.550	-1.162	-.511
37.5	.377	.856	1.142	1.058	1.100	.256	.048	.080	.036	.004	-.011	-.236	-1.367	-1.442	-1.442	-1.081	-.476
35.0	.384	.872	1.163	1.078	1.161	.224	.044	.073	.033	.003	-.008	-.171	-1.330	-1.334	-1.334	-1.001	-.440
34.0	.389	.883	1.177	1.092	1.131	.228	.044	.074	.033	.003	-.007	-.157	-1.279	-1.336	-1.336	-1.002	-.441
33.0	.393	.894	1.192	1.105	1.100	.231	.044	.075	.033	.003	-.006	-.143	-1.227	-1.338	-1.338	-1.004	-.442
32.0	.398	.904	1.206	1.118	1.069	.235	.044	.077	.033	.003	-.006	-.128	-1.176	-1.340	-1.340	-1.005	-.442
31.0	.403	.915	1.220	1.131	1.038	.238	.044	.078	.034	.003	-.005	-.114	-1.124	-1.342	-1.342	-1.007	-.443
30.0	.407	.926	1.234	1.144	1.008	.242	.044	.079	.034	.003	-.004	-.099	-1.073	-1.344	-1.344	-1.008	-.443
29.0	.395	.898	1.197	1.110	.984	.251	.046	.081	.036	.003	-.005	-.107	-1.029	-1.340	-1.340	-1.005	-.442
28.0	.383	.870	1.160	1.076	.961	.260	.047	.084	.038	.003	-.006	-.115	-.984	-1.336	-1.336	-1.002	-.441
27.0	.371	.842	1.123	1.042	.937	.269	.049	.086	.040	.003	-.007	-.123	-.940	-1.332	-1.332	-.999	-.440
26.0	.358	.815	1.086	1.007	.914	.278	.050	.088	.042	.004	-.008	-.131	-.896	-1.328	-1.328	-.996	-.438
25.0	.346	.787	1.049	.973	.891	.287	.052	.091	.044	.004	-.009	-.139	-.852	-1.324	-1.324	-.993	-.437
24.0	.343	.778	1.038	.965	.867	.296	.053	.093	.046	.004	-.009	-.147	-.807	-1.315	-1.315	-.987	-.434
23.0	.339	.770	1.027	.956	.844	.305	.055	.095	.048	.004	-.010	-.155	-.763	-1.306	-1.306	-.980	-.431
22.0	.335	.762	1.016	.948	.820	.314	.056	.098	.050	.004	-.011	-.163	-.719	-1.297	-1.297	-.973	-.428
21.0	.332	.754	1.005	.940	.797	.323	.058	.100	.051	.004	-.012	-.171	-.674	-1.288	-1.288	-.966	-.425
20.0	.328	.745	.994	.931	.773	.332	.060	.102	.053	.004	-.013	-.179	-.630	-1.279	-1.279	-.959	-.422
19.0	.355	.806	1.075	1.004	.974	.692	.218	.144	.018	-.037	-.110	-.393	-.862	-1.322	-1.322	-.991	-.436
18.0	.382	.867	1.157	1.077	1.175	1.053	.376	.186	-.017	-.079	-.208	-.607	-1.094	-1.364	-1.364	-1.023	-.450
17.0	.409	.928	1.238	1.150	1.376	1.413	.534	.228	-.053	-.120	-.305	-.821	-1.326	-1.407	-1.407	-1.055	-.464
16.0	.445	1.012	1.350	1.251	1.564	1.582	.622	.241	-.080	-.142	-.373	-.943	-1.498	-1.469	-1.469	-1.102	-.485
15.0	.549	1.249	1.665	1.554	1.703	.948	.426	.136	-.081	-.083	-.322	-.666	-1.430	-1.705	-1.705	-1.279	-.563
14.0	.673	1.530	2.040	1.907	1.841	.363	.230	.045	-.082	-.017	-.270	-.410	-1.362	-1.944	-1.944	-1.458	-.642
13.0	.801	1.820	2.426	2.268	1.980	-.100	.038	-.010	-.083	.053	-.214	-.213	-1.294	-2.185	-2.185	-1.639	-.721
12.0	.932	2.118	2.823	2.639	2.118	-.100	-.083	-.040	-.087	.100	-.156	-.134	-1.226	-2.426	-2.426	-1.820	-.801
10.0	-.062	.064	.365	-.099	-.100	-.100	-.100	-.100	.045	.088	.100	.100	.100	.100	.100	.100	.100
8.0	-.100	-.067	-.100	-.100	-.100	-.100	-.100	-.100	.039	.056	.100	.100	.100	.100	.100	.100	.100
6.0	.064	-.016	-.100	-.100	-.100	-.100	-.100	-.078	-.004	.057	.100	.100	.100	.100	.058	.084	-.154
4.0	.499	.538	1.199	.961	-.100	-.100	-.100	-.046	.032	.090	.100	.100	.089	-.563	-1.363	-.700	-.458
2.0	.607	1.030	2.091	2.001	1.213	.381	-.100	-.100	.060	.079	.098	-.120	-.785	-1.932	-2.153	-1.109	-.681
0.0	.443	.829	1.697	1.715	1.189	.765	.052	-.082	.097	.094	.031	-.491	-.903	-1.695	-1.676	-.823	-.510

KFF (IN UNITS OF KMSQ/SEC) FOR OCTOBER

				SOUTH				LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47.5	3.804	3.187	3.414	2.989	2.046	1.319	1.070	.880	.618	.542	.982	1.748	3.246	2.783	3.965	4.959	4.979
45.0	3.086	2.721	3.172	2.762	1.820	1.114	.861	.745	.496	.406	.813	1.563	3.041	2.667	3.628	4.715	4.793
42.5	2.479	2.219	2.887	2.501	1.621	.881	.682	.613	.408	.329	.587	1.275	2.562	2.349	3.038	4.508	4.611
40.0	1.871	1.715	2.603	2.239	1.422	.648	.502	.481	.319	.252	.362	.986	2.083	2.030	2.449	4.300	4.430
37.5	1.557	1.433	2.279	2.051	1.345	.534	.426	.400	.264	.190	.266	.719	1.832	1.705	1.999	3.659	3.874
35.0	1.242	1.151	1.955	1.863	1.269	.420	.350	.319	.209	.128	.171	.451	1.581	1.379	1.550	3.018	3.319
34.0	1.170	1.080	1.871	1.821	1.199	.412	.338	.312	.203	.119	.150	.405	1.478	1.334	1.445	2.772	3.035
33.0	1.098	1.011	1.787	1.778	1.130	.405	.327	.306	.197	.110	.129	.359	1.374	1.289	1.341	2.526	2.751
32.0	1.025	.941	1.702	1.736	1.061	.397	.315	.300	.190	.100	.108	.312	1.270	1.244	1.237	2.281	2.467
31.0	.953	.872	1.618	1.693	.992	.390	.303	.294	.184	.091	.087	.266	1.166	1.199	1.133	2.034	2.184
30.0	.880	.802	1.534	1.650	.923	.382	.292	.287	.178	.082	.067	.219	1.063	1.153	1.028	1.789	1.900
29.0	.982	.913	1.512	1.572	.885	.383	.292	.286	.180	.094	.077	.227	1.004	1.123	1.053	1.739	1.838
28.0	1.084	1.023	1.491	1.493	.847	.384	.292	.286	.183	.106	.088	.234	.944	1.093	1.077	1.689	1.776
27.0	1.185	1.134	1.469	1.414	.809	.385	.293	.285	.186	.118	.099	.242	.884	1.063	1.102	1.639	1.715
26.0	1.287	1.245	1.448	1.335	.771	.386	.293	.284	.188	.129	.109	.249	.825	1.033	1.126	1.589	1.654
25.0	1.389	1.356	1.426	1.257	.733	.388	.293	.283	.191	.141	.120	.256	.765	1.002	1.151	1.539	1.592
24.0	1.490	1.467	1.405	1.178	.696	.389	.294	.282	.194	.153	.130	.264	.706	.972	1.175	1.489	1.531
23.0	1.592	1.577	1.384	1.099	.658	.390	.294	.281	.196	.165	.141	.272	.646	.942	1.199	1.440	1.469
22.0	1.693	1.688	1.362	1.020	.620	.391	.294	.280	.198	.177	.152	.279	.586	.911	1.224	1.389	1.408
21.0	1.795	1.799	1.341	.942	.583	.392	.294	.279	.201	.189	.163	.287	.526	.881	1.248	1.339	1.346
20.0	1.897	1.910	1.319	.863	.545	.393	.294	.278	.203	.200	.174	.294	.467	.851	1.273	1.290	1.285
19.0	1.783	1.876	1.377	.957	.723	.623	.448	.373	.249	.255	.273	.441	.625	.946	1.261	1.265	1.254
18.0	1.670	1.843	1.434	1.051	.902	.853	.603	.468	.295	.310	.371	.587	.784	1.042	1.250	1.239	1.222
17.0	1.556	1.809	1.492	1.146	1.081	1.083	.757	.563	.341	.365	.470	.733	.943	1.138	1.238	1.214	1.191
16.0	1.466	1.795	1.586	1.315	1.345	1.387	.947	.658	.390	.423	.590	.931	1.182	1.326	1.295	1.229	1.194
15.0	1.475	1.859	1.826	1.787	1.951	1.986	1.283	.756	.452	.495	.797	1.338	1.743	1.881	1.628	1.401	1.333
14.0	1.483	1.924	2.066	2.259	2.556	2.584	1.619	.854	.514	.567	1.003	1.744	2.304	2.437	1.960	1.573	1.472
13.0	1.492	1.988	2.306	2.730	3.162	3.183	1.955	.952	.576	.639	1.209	2.150	2.865	2.992	2.293	1.746	1.612
12.0	1.500	2.053	2.545	3.201	3.767	3.781	2.290	1.049	.638	.711	1.416	2.556	3.426	3.548	2.625	1.918	1.751
10.0	2.298	3.101	3.988	4.774	4.597	3.428	1.861	.853	.477	.541	1.089	2.234	3.660	4.365	3.630	2.781	2.670
8.0	2.575	3.405	4.153	4.686	4.005	2.502	1.263	.601	.300	.363	.725	1.616	3.032	3.985	3.515	2.899	2.855
6.0	1.994	2.603	2.979	3.196	2.601	1.590	.761	.372	.181	.246	.466	1.033	1.921	2.634	2.407	2.117	2.170
4.0	1.279	1.633	1.919	2.055	1.678	1.110	.500	.263	.145	.207	.347	.724	1.201	1.668	1.555	1.329	1.379
2.0	.841	.978	1.187	1.315	1.128	.779	.361	.205	.143	.182	.278	.528	.792	1.064	1.043	.838	.849
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

V (IN UNITS OF .001 KM/SEC) FOR OCTOBER

	SOUTH						LATITUDE (DEGREES)						NORTH				
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	.091	.134	.144	.133	.065	-.032	-.057	-.016	.021	.028	.034	-.057	-.143	-.136	-.132	-.128	-.104
47.5	.000	.012	-.113	-.213	-.339	-.458	-.465	-.403	-.330	-.257	-.243	-.303	-.367	-.410	-.445	-.419	-.277
45.0	-.011	.017	-.055	-.145	-.257	-.352	-.371	-.322	-.266	-.211	-.181	-.219	-.283	-.325	-.330	-.273	-.147
42.5	.064	.098	.102	.067	-.022	-.095	-.126	-.097	-.094	-.084	-.067	-.112	-.212	-.266	-.224	-.128	-.037
40.0	.118	.159	.213	.216	.159	.122	.091	.081	.046	.015	-.018	-.073	-.182	-.289	-.229	-.055	.077
37.5	.082	.145	.217	.201	.168	.170	.165	.125	.072	.009	-.049	-.075	-.127	-.274	-.282	-.086	.136
35.0	.021	.112	.189	.137	.083	.091	.105	.055	.009	-.052	-.093	-.073	-.065	-.213	-.336	-.207	.103
34.0	.011	.102	.178	.121	.049	.041	.051	.006	-.026	-.073	-.094	-.062	-.044	-.183	-.338	-.229	.123
33.0	.012	.089	.157	.107	.026	-.011	-.011	-.046	-.059	-.087	-.086	-.052	-.032	-.164	-.322	-.236	.082
32.0	.013	.070	.126	.088	.012	-.053	-.065	-.089	-.080	-.090	-.072	-.043	-.029	-.150	-.293	-.220	.062
31.0	.011	.050	.097	.074	.007	-.077	-.099	-.114	-.085	-.079	-.048	-.027	-.025	-.131	-.244	-.167	.091
30.0	.004	.031	.071	.060	.006	-.086	-.116	-.123	-.079	-.061	-.021	-.010	-.022	-.114	-.192	-.129	.037
29.0	-.004	.020	.056	.047	.003	-.086	-.117	-.113	-.063	-.037	.007	.009	-.014	-.089	-.139	-.079	.050
28.0	-.006	.024	.054	.042	-.003	-.084	-.109	-.090	-.039	-.009	.038	.035	.003	-.057	-.096	-.038	.093
27.0	.002	.043	.063	.041	-.010	-.075	-.090	-.052	-.004	.030	.078	.075	.045	-.004	-.043	.018	.193
26.0	.016	.072	.079	.045	-.013	-.069	-.078	-.024	.019	.059	.105	.107	.084	.039	-.012	.049	.260
25.0	.035	.099	.096	.050	-.012	-.067	-.080	-.020	.020	.065	.103	.111	.099	.053	-.015	.035	.241
24.0	.050	.121	.112	.060	-.004	-.045	-.066	-.013	.027	.077	.102	.115	.116	.077	.008	.065	.301
23.0	.056	.135	.126	.077	.017	-.011	-.042	-.006	.034	.084	.093	.106	.115	.087	.029	.096	.345
22.0	.053	.138	.138	.101	.047	.014	-.032	-.016	.026	.071	.064	.068	.076	.057	.014	.074	.263
21.0	.041	.135	.151	.126	.071	.028	-.027	-.024	.023	.063	.047	.037	.039	.029	.012	.074	.219
20.0	.025	.128	.163	.141	.081	.035	-.021	-.025	.033	.074	.051	.023	.017	.012	.027	.103	.240
19.0	.009	.122	.169	.142	.093	.057	-.022	-.040	.052	.113	.072	.015	-.006	-.008	.035	.122	.251
18.0	-.010	.123	.192	.165	.134	.112	-.047	-.105	.119	.267	.178	.048	.001	.009	.083	.198	.398
17.0	-.015	.103	.181	.171	.145	.165	-.126	-.260	.104	.392	.341	.152	.039	.036	.149	.295	.556
16.0	-.002	.048	.097	.111	.087	.160	-.280	-.515	-.126	.293	.421	.250	.037	-.033	.108	.242	.357
15.0	-.001	-.017	-.003	.018	.005	.080	-.469	-.829	-.495	.017	.347	.248	-.055	-.228	-.098	-.030	-.252
14.0	-.031	-.060	-.059	-.043	-.047	.009	-.542	-1.033	-.771	-.205	.231	.203	-.135	-.368	-.252	-.203	-.584
13.0	-.081	-.066	-.042	-.031	-.024	-.018	-.470	-1.068	-.821	-.229	.175	.164	-.152	-.368	-.250	-.148	-.383
12.0	-.106	-.052	.003	.031	.032	-.025	-.353	-.957	-.706	-.133	.181	.135	-.146	-.310	-.197	-.058	-.115
10.0	-.060	-.031	.031	.109	.073	-.034	-.206	-.553	-.382	.011	.172	.100	-.120	-.223	-.144	-.028	-.001
8.0	-.022	-.025	.019	.085	.053	-.049	-.143	-.212	-.133	.044	.095	.070	-.082	-.172	-.121	-.027	-.012
6.0	-.010	-.020	.000	.009	.012	-.049	-.044	-.008	.008	.025	.037	.046	-.014	-.073	-.049	.008	.019
4.0	.020	-.005	-.018	-.048	-.025	-.019	.109	.212	.138	-.007	-.049	-.028	.053	.085	.049	.008	-.004
2.0	.033	.012	-.039	-.076	-.054	.028	.259	.530	.330	-.033	-.202	-.143	.079	.205	.124	-.000	-.018
0.0	.008	.003	-.056	-.087	-.066	.082	.369	.573	.236	-.206	-.247	-.036	.134	.206	.103	.004	-.052

W (IN UNITS OF .000001 KM/SEC)   FOR OCTOBER

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	10	20	30	40	NORTH 50	60	70	80
50.0	-3.380	-3.510	-1.860	-.249	.712	.904	.520	.687	.426	-.296	-.084	.178	-.203	-.025	-.337	-.192	1.130
47.5	-2.435	-2.685	-1.700	-.423	.181	.413	.428	.641	.393	-.103	-.093	.003	-.121	.147	.026	.440	1.855
45.0	-1.790	-1.990	-1.550	-.631	-.223	.074	.325	.570	.447	.051	-.074	-.061	-.054	.218	.290	.853	2.090
42.5	-1.230	-1.390	-1.230	-.645	-.390	-.101	.231	.494	.365	.123	-.001	-.134	-.089	.260	.442	.943	1.805
40.0	-.508	-.752	-.695	-.450	-.419	-.149	.125	.387	.198	.096	-.032	-.244	-.226	.287	.636	.934	1.3[illegible]0
37.5	.032	-.259	-.228	-.224	-.299	-.098	.041	.216	.044	-.022	-.132	-.281	-.334	.159	.901	1.060	.802
35.0	.263	.100	.047	-.160	-.185	.001	.019	.032	-.076	-.155	-.152	-.176	-.317	-.114	.918	1.300	.564
34.0	.299	.213	.115	-.178	-.178	.025	.013	-.025	-.096	-.180	-.131	-.116	-.293	-.224	.833	1.410	.595
33.0	.321	.299	.167	-.201	-.193	.024	.006	-.064	-.097	-.184	-.096	-.065	-.269	-.319	.728	1.490	.662
32.0	.332	.353	.203	-.215	-.223	-.007	.001	-.083	-.079	-.173	-.052	-.030	-.246	-.395	.630	1.530	.726
31.0	.328	.375	.225	-.218	-.254	-.059	-.004	-.086	-.045	-.151	-.008	-.012	-.229	-.445	.551	1.530	.760
30.0	.309	.373	.236	-.208	-.280	-.120	-.010	-.077	.001	-.123	.033	-.012	-.217	-.469	.495	1.490	.750
29.0	.277	.358	.239	-.194	-.295	-.177	-.015	-.059	.048	-.092	.066	-.025	-.212	-.466	.456	1.400	.700
28.0	.243	.341	.235	-.181	-.303	-.223	-.015	-.031	.088	-.062	.091	-.048	-.211	-.446	.418	1.300	.622
27.0	.221	.333	.224	-.175	-.308	-.250	-.008	.006	.115	-.029	.109	-.072	-.214	-.420	.370	1.190	.533
26.0	.224	.339	.206	-.176	-.314	-.250	.006	.053	.129	.006	.120	-.091	-.217	-.404	.309	1.100	.447
25.0	.253	.358	.183	-.184	-.320	-.250	.021	.102	.134	.043	.122	-.098	-.219	-.400	.234	1.020	.368
24.0	.305	.386	.159	-.195	-.324	-.250	.026	.146	.137	.078	.114	-.090	-.215	-.404	.157	.957	.293
23.0	.366	.420	.140	-.201	-.321	-.230	.016	.178	.142	.106	.093	-.071	-.206	-.405	.088	.900	.217
22.0	.423	.457	.132	-.194	-.310	-.210	-.008	.192	.151	.120	.063	-.051	-.191	-.392	.038	.844	.136
21.0	.465	.498	.141	-.173	-.297	-.210	-.041	.192	.164	.120	.028	-.038	-.171	-.362	.014	.782	.054
20.0	.488	.544	.166	-.148	-.291	-.210	-.070	.185	.182	.111	-.006	-.039	-.148	-.320	.020	.716	-.020
19.0	.491	.591	.199	-.129	-.287	-.210	-.097	.179	.210	.098	-.046	-.056	-.128	-.271	.062	.652	-.074
18.0	.482	.636	.228	-.113	-.257	-.210	-.158	.181	.280	.090	-.116	-.095	-.112	-.217	.106	.590	-.101
17.0	.459	.703	.285	-.083	-.213	-.230	-.309	.219	.537	.097	-.286	-.194	-.107	-.153	.158	.538	-.102
16.0	.424	.707	.322	-.044	-.171	-.230	-.607	.248	.885	.221	-.380	-.372	-.174	-.098	.240	.462	-.083
15.0	.368	.621	.314	-.010	-.144	-.250	-1.040	.221	1.230	.493	-.301	-.579	-.332	-.064	.378	.370	-.056
14.0	.282	.484	.266	.006	-.133	-.330	-1.530	.088	1.530	.866	-.078	-.749	-.550	-.050	.563	.299	-.033
13.0	.165	.372	.216	.008	-.123	-.400	-1.940	-.173	1.810	1.240	.155	-.853	-.760	-.037	.749	.284	-.022
12.0	.038	.336	.202	.016	-.109	-.500	-2.200	-.515	2.140	1.540	.282	-.921	-.909	-.004	.888	.324	-.024
10.0	-.138	.348	.274	.094	-.162	-.660	-2.300	-1.070	2.640	1.880	.309	-1.070	-1.060	.089	1.000	.421	-.058
8.0	-.162	.295	.342	.193	-.277	-.740	-2.100	-1.040	2.530	1.900	.218	-1.050	-1.140	.142	1.000	.474	-.126
6.0	-.170	.234	.352	.206	-.312	-.753	-1.740	-.758	2.140	1.660	.132	-.883	-1.150	.130	.983	.507	-.226
4.0	-.151	.162	.277	.129	-.224	-.658	-1.270	-.600	1.700	1.300	.159	-.722	-.969	.060	.830	.421	-.249
2.0	-.065	.067	.162	.052	-.114	-.391	-.683	-.407	1.020	.759	.124	-.452	-.518	.003	.437	.217	-.121
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

T (IN UNITS OF 100. DEGREES KELVIN) FOR JANUARY

	SOUTH							LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	2.900	2.851	2.801	2.770	2.753	2.738	2.724	2.715	2.717	2.715	2.700	2.664	2.615	2.564	2.498	2.476	2.473
47.5	2.871	2.838	2.798	2.767	2.745	2.727	2.711	2.703	2.708	2.711	2.696	2.662	2.614	2.532	2.457	2.431	2.440
45.0	2.813	2.794	2.763	2.732	2.705	2.690	2.683	2.679	2.685	2.687	2.672	2.639	2.582	2.487	2.411	2.381	2.398
42.5	2.742	2.727	2.703	2.675	2.655	2.645	2.643	2.645	2.651	2.651	2.636	2.603	2.538	2.443	2.366	2.335	2.351
40.0	2.668	2.657	2.639	2.615	2.598	2.592	2.595	2.599	2.604	2.602	2.586	2.552	2.485	2.393	2.322	2.290	2.303
37.5	2.598	2.589	2.575	2.556	2.539	2.533	2.537	2.542	2.544	2.539	2.525	2.492	2.429	2.339	2.270	2.245	2.252
35.0	2.537	2.529	2.516	2.497	2.478	2.470	2.473	2.477	2.477	2.472	2.460	2.431	2.371	2.287	2.221	2.197	2.197
34.0	2.515	2.507	2.493	2.472	2.454	2.444	2.446	2.449	2.450	2.444	2.433	2.405	2.348	2.268	2.202	2.176	2.176
33.0	2.494	2.486	2.471	2.449	2.428	2.418	2.417	2.420	2.422	2.416	2.406	2.381	2.326	2.251	2.186	2.156	2.155
32.0	2.475	2.466	2.450	2.426	2.403	2.390	2.387	2.390	2.393	2.387	2.379	2.355	2.304	2.235	2.170	2.136	2.133
31.0	2.458	2.447	2.430	2.404	2.378	2.363	2.358	2.360	2.363	2.359	2.352	2.329	2.282	2.220	2.157	2.119	2.111
30.0	2.442	2.430	2.411	2.383	2.354	2.337	2.330	2.329	2.333	2.331	2.325	2.305	2.261	2.208	2.145	2.104	2.094
29.0	2.426	2.415	2.393	2.363	2.331	2.311	2.301	2.299	2.302	2.302	2.298	2.280	2.244	2.197	2.136	2.092	2.079
28.0	2.412	2.399	2.377	2.344	2.309	2.284	2.272	2.270	2.272	2.273	2.270	2.256	2.229	2.188	2.130	2.083	2.068
27.0	2.400	2.385	2.361	2.325	2.285	2.259	2.244	2.241	2.242	2.243	2.240	2.231	2.215	2.179	2.125	2.077	2.060
26.0	2.389	2.373	2.347	2.307	2.263	2.233	2.217	2.212	2.213	2.214	2.213	2.209	2.202	2.173	2.121	2.074	2.057
25.0	2.380	2.363	2.336	2.291	2.243	2.209	2.191	2.184	2.182	2.185	2.188	2.186	2.192	2.166	2.117	2.072	2.055
24.0	2.372	2.355	2.326	2.278	2.224	2.186	2.165	2.155	2.152	2.156	2.160	2.164	2.182	2.161	2.115	2.072	2.055
23.0	2.364	2.348	2.318	2.265	2.207	2.164	2.139	2.127	2.121	2.127	2.131	2.143	2.171	2.157	2.116	2.074	2.057
22.0	2.359	2.342	2.311	2.254	2.190	2.142	2.113	2.098	2.091	2.097	2.103	2.123	2.161	2.155	2.119	2.081	2.062
21.0	2.353	2.337	2.304	2.244	2.175	2.121	2.085	2.068	2.061	2.065	2.075	2.104	2.151	2.154	2.122	2.088	2.069
20.0	2.345	2.331	2.298	2.236	2.163	2.100	2.057	2.036	2.030	2.034	2.048	2.086	2.142	2.153	2.125	2.097	2.077
19.0	2.338	2.324	2.291	2.229	2.152	2.082	2.031	2.004	1.997	2.005	2.025	2.073	2.135	2.153	2.127	2.103	2.086
18.0	2.330	2.318	2.285	2.224	2.144	2.068	2.010	1.977	1.969	1.982	2.009	2.064	2.130	2.152	2.129	2.109	2.093
17.0	2.319	2.310	2.280	2.222	2.140	2.060	1.996	1.962	1.958	1.975	2.004	2.060	2.128	2.152	2.130	2.114	2.099
16.0	2.307	2.299	2.273	2.219	2.140	2.060	2.003	1.978	1.980	1.993	2.016	2.064	2.128	2.148	2.131	2.117	2.105
15.0	2.294	2.287	2.264	2.216	2.144	2.077	2.039	2.028	2.034	2.040	2.053	2.082	2.132	2.146	2.133	2.121	2.111
14.0	2.280	2.274	2.254	2.212	2.155	2.114	2.098	2.099	2.103	2.105	2.107	2.110	2.140	2.147	2.136	2.126	2.117
13.0	2.264	2.262	2.245	2.210	2.177	2.168	2.167	2.171	2.175	2.179	2.169	2.151	2.154	2.151	2.141	2.133	2.124
12.0	2.243	2.248	2.238	2.214	2.211	2.229	2.238	2.244	2.247	2.250	2.234	2.206	2.177	2.158	2.145	2.139	2.131
10.0	2.186	2.210	2.242	2.277	2.325	2.367	2.383	2.389	2.388	2.382	2.368	2.330	2.265	2.202	2.163	2.152	2.144
8.0	2.194	2.232	2.309	2.402	2.470	2.504	2.519	2.525	2.525	2.516	2.493	2.449	2.380	2.297	2.229	2.193	2.179
6.0	2.309	2.360	2.441	2.530	2.594	2.629	2.647	2.656	2.654	2.643	2.618	2.571	2.498	2.417	2.344	2.295	2.268
4.0	2.423	2.488	2.568	2.639	2.699	2.743	2.768	2.778	2.779	2.766	2.736	2.681	2.605	2.525	2.456	2.404	2.373
2.0	2.525	2.591	2.658	2.721	2.788	2.844	2.873	2.886	2.891	2.879	2.845	2.777	2.695	2.618	2.555	2.502	2.452
0.0	2.604	2.661	2.718	2.781	2.860	2.932	2.965	2.980	2.986	2.978	2.939	2.858	2.762	2.673	2.591	2.509	2.427

KZZ (IN UNITS OF .00001 KMSQ/SEC)　　FOR　JANUARY

	SOUTH							LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	2.353	1.363	1.533	1.761	.540	.284	.244	.229	.363	.224	.247	1.174	5.953	6.663	3.247	2.640	2.775
47.5	2.014	1.166	1.312	1.507	.462	.243	.209	.196	.311	.191	.211	1.005	5.094	5.702	2.779	2.259	2.375
45.0	1.675	.969	1.091	1.253	.384	.202	.174	.163	.258	.159	.176	.835	4.236	4.741	2.311	1.878	1.975
42.5	1.335	.773	.870	.999	.306	.161	.139	.130	.206	.127	.140	.666	3.377	3.780	1.842	1.498	1.575
40.0	.996	.576	.649	.745	.229	.120	.103	.097	.154	.095	.104	.497	2.519	2.819	1.374	1.117	1.174
37.5	.849	.491	.553	.635	.195	.102	.088	.082	.131	.081	.089	.423	2.147	2.403	1.171	.952	1.001
35.0	.702	.406	.457	.525	.161	.085	.073	.068	.108	.067	.074	.350	1.775	1.987	.968	.787	.827
34.0	.643	.372	.419	.491	.147	.078	.067	.062	.099	.061	.067	.321	1.626	1.820	.887	.721	.758
33.0	.584	.338	.380	.437	.134	.070	.061	.057	.090	.055	.061	.291	1.477	1.653	.806	.655	.689
32.0	.525	.304	.342	.393	.120	.063	.054	.051	.081	.050	.055	.262	1.328	1.487	.725	.589	.619
31.0	.466	.270	.304	.349	.107	.056	.048	.045	.072	.044	.049	.233	1.179	1.320	.643	.523	.550
30.0	.407	.236	.265	.305	.093	.049	.042	.040	.063	.039	.043	.203	1.031	1.154	.562	.457	.480
29.0	.373	.216	.243	.279	.086	.045	.039	.036	.057	.035	.039	.186	.943	1.056	.514	.418	.440
28.0	.338	.196	.220	.253	.078	.041	.035	.033	.052	.032	.035	.169	.856	.958	.467	.379	.399
27.0	.304	.176	.198	.227	.070	.037	.032	.030	.047	.029	.032	.151	.768	.860	.419	.341	.358
26.0	.269	.156	.175	.201	.062	.032	.028	.026	.041	.026	.028	.134	.681	.762	.371	.302	.317
25.0	.234	.136	.153	.175	.054	.028	.024	.023	.036	.022	.025	.117	.593	.664	.324	.263	.277
24.0	.200	.116	.130	.150	.046	.024	.021	.019	.031	.019	.021	.100	.506	.566	.276	.224	.236
23.0	.165	.096	.108	.124	.038	.020	.017	.016	.025	.016	.017	.082	.418	.468	.228	.185	.195
22.0	.131	.076	.085	.098	.030	.016	.014	.013	.020	.012	.014	.065	.331	.370	.180	.147	.154
21.0	.096	.056	.063	.072	.022	.012	.010	.009	.015	.009	.010	.048	.243	.272	.133	.108	.113
20.0	.062	.036	.040	.046	.014	.007	.006	.006	.009	.006	.006	.031	.156	.174	.085	.069	.073
19.0	.041	.041	.042	.056	.045	.019	.016	.012	.010	.008	.019	.075	.161	.167	.089	.089	.089
18.0	.043	.043	.044	.066	.076	.031	.026	.017	.010	.010	.032	.120	.167	.159	.093	.093	.093
17.0	.044	.044	.046	.076	.107	.043	.036	.023	.010	.012	.044	.165	.173	.151	.097	.097	.097
16.0	.048	.048	.048	.086	.138	.056	.046	.028	.011	.016	.056	.196	.174	.143	.101	.101	.101
15.0	.064	.064	.064	.113	.136	.055	.044	.027	.014	.026	.061	.171	.156	.139	.102	.102	.102
14.0	.080	.080	.080	.140	.135	.054	.041	.026	.017	.036	.066	.146	.139	.136	.103	.103	.103
13.0	.096	.096	.096	.167	.133	.053	.039	.026	.023	.047	.071	.121	.122	.132	.104	.104	.104
12.0	.054	.059	.140	.195	.131	.052	.052	.036	.032	.061	.090	.095	.105	.128	.106	.107	.107
10.0	.076	.072	.135	.177	.266	.091	.092	.067	.061	.104	.143	.151	.387	.125	.090	.090	.090
8.0	.102	.070	.155	.217	.380	.160	.160	.124	.115	.178	.229	.239	.506	.274	.095	.097	.097
6.0	.093	.090	.262	.352	.532	.280	.281	.231	.219	.303	.366	.378	.663	.415	.113	.102	.077
4.0	.212	.227	.468	.572	.748	.490	.491	.431	.416	.517	.586	.598	.869	.634	.267	.247	.210
2.0	.562	.581	.838	.926	1.057	.857	.858	.804	.790	.881	.937	.947	1.141	.973	.633	.605	.562
0.0	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500

KFZ (IN UNITS OF .001 KMSQ/SEC)   FOR JANUARY

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	10	20	30	40	NORTH 50	60	70	80
50.0	.046	.104	.138	.145	.026	.038	.024	.030	.014	.004	.011	-.547	-2.343	-1.930	-1.930	-1.447	-.637
47.5	.048	.109	.145	.153	.026	.038	.023	.029	.014	.003	.012	-.547	-2.343	-1.930	-1.930	-1.447	-.637
45.0	.050	.114	.152	.160	.025	.039	.022	.029	.014	.002	.012	-.581	-2.613	-2.220	-2.220	-1.665	-.732
42.5	.049	.111	.149	.157	.021	.039	.021	.028	.013	.002	.009	-.511	-2.589	-2.280	-2.280	-1.710	-.752
40.0	.048	.109	.145	.154	.017	.038	.020	.026	.012	.002	.007	-.440	-2.565	-2.340	-2.340	-1.755	-.772
37.5	.046	.104	.139	.148	.005	.042	.020	.027	.012	.002	.005	-.346	-2.637	-2.303	-2.303	-1.727	-.760
35.0	.043	.099	.132	.141	-.007	.046	.020	.027	.012	.002	.004	-.253	-2.709	-2.266	-2.266	-1.699	-.748
34.0	.044	.100	.133	.142	-.001	.045	.020	.027	.013	.002	.003	-.244	-2.606	-2.293	-2.293	-1.720	-.757
33.0	.044	.101	.134	.144	.006	.044	.020	.028	.013	.001	.003	-.236	-2.502	-2.321	-2.321	-1.741	-.766
32.0	.045	.101	.135	.145	.012	.043	.020	.028	.013	.001	.002	-.227	-2.398	-2.349	-2.349	-1.762	-.775
31.0	.045	.102	.136	.146	.018	.042	.020	.029	.014	.001	.002	-.219	-2.295	-2.377	-2.377	-1.783	-.784
30.0	.045	.103	.137	.147	.024	.042	.020	.029	.014	.001	.001	-.210	-2.191	-2.405	-2.405	-1.804	-.794
29.0	.051	.116	.154	.164	.036	.044	.022	.030	.014	.001	.002	-.224	-2.105	-2.350	-2.350	-1.762	-.775
28.0	.056	.128	.171	.180	.048	.047	.023	.031	.014	.002	.003	-.237	-2.018	-2.294	-2.294	-1.721	-.757
27.0	.062	.141	.188	.197	.060	.049	.025	.032	.014	.002	.003	-.250	-1.931	-2.239	-2.239	-1.679	-.739
26.0	.068	.153	.205	.213	.072	.052	.027	.033	.014	.003	.004	-.263	-1.844	-2.184	-2.184	-1.638	-.721
25.0	.073	.166	.221	.230	.083	.055	.028	.034	.014	.003	.005	-.276	-1.758	-2.129	-2.129	-1.597	-.703
24.0	.078	.177	.236	.244	.095	.057	.030	.035	.014	.004	.005	-.290	-1.671	-2.131	-2.131	-1.598	-.703
23.0	.083	.188	.251	.259	.107	.060	.031	.036	.014	.004	.006	-.303	-1.584	-2.134	-2.134	-1.600	-.704
22.0	.088	.199	.266	.273	.119	.062	.033	.037	.014	.005	.006	-.316	-1.498	-2.136	-2.136	-1.602	-.705
21.0	.092	.210	.280	.287	.131	.065	.035	.037	.015	[illegible]	.007	-.329	-1.411	-2.138	-2.138	-1.604	-.706
20.0	.097	.221	.295	.302	.142	.068	.036	.038	.015	[illegible]	[illegible]	-.343	-1.324	-2.141	-2.141	-1.606	-.706
19.0	.129	.292	.390	.398	.367	.195	.127	.095	.036	[illegible]	[illegible]	-.801	-1.466	-2.127	-2.127	-1.596	-.702
18.0	.160	.363	.484	.493	.591	.322	.218	.151	.058	[illegible]	[illegible]	1.260	-1.607	-2.114	-2.114	-1.586	-.698
17.0	.191	.434	.579	.589	.816	.449	.309	.207	.080	-.088	[illegible]	-1.718	-1.748	-2.101	-2.101	-1.576	-.693
16.0	.237	.538	.718	.729	.995	.532	.373	.244	.080	-.090	-.630	-1.934	-1.845	-2.082	-2.082	-1.561	-.687
15.0	.335	.760	1.014	1.026	.994	.420	.331	.201	.036	.023	-.379	-1.131	-1.763	-2.414	-2.414	-1.810	-.796
14.0	.431	.979	1.306	1.321	.993	.316	.289	.159	-.012	.094	-.128	-.390	-1.681	-2.744	-2.744	-2.058	-.906
13.0	.528	1.199	1.599	1.616	.992	.233	.248	.112	-.060	.100	.093	.100	-1.600	-3.075	-3.075	-2.306	-1.015
12.0	.625	1.420	1.893	1.914	.991	.211	.204	.063	-.107	.100	.100	.100	-1.518	-3.404	-3.404	-2.553	-1.123
10.0	-.054	.187	.185	-.100	-.100	-.100	-.100	-.094	.100	.100	.100	.100	.100	.100	.030	.100	.100
8.0	-.100	.042	-.100	-.100	-.100	-.100	-.100	-.024	.100	.100	.100	.100	.100	.100	.100	.096	.100
6.0	.149	.517	.164	-.100	-.100	-.100	-.081	.188	.001	.100	.098	.100	.100	.100	-.141	.094	.100
4.0	.476	.916	.664	.191	-.067	-.100	-.098	.012	.032	-.008	.100	.100	.100	-1.493	-1.829	-.165	-.134
2.0	.677	1.168	.966	.641	.420	-.028	-.098	-.029	.090	.040	.070	-.387	-1.554	-3.238	-2.676	-.764	-.395
0.0	.549	.915	.754	.486	.383	.231	-.070	.130	.106	.072	-.214	-1.042	-1.709	-2.868	-1.975	-.572	-.300

KFF (IN UNITS OF KMSQ/SEC) FOR JANUARY

	SOUTH						LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47.5	.433	.440	.329	.315	.353	.560	.383	.419	.863	1.038	1.778	2.542	5.072	6.157	7.293	7.576	7.325
45.0	.394	.362	.242	.258	.308	.468	.281	.323	.695	.861	1.475	2.195	4.632	5.832	7.023	7.422	6.686
42.5	.374	.361	.199	.216	.259	.386	.249	.273	.567	.689	1.064	1.723	4.020	5.232	6.255	6.457	6.017
40.0	.353	.350	.155	.172	.209	.304	.218	.224	.439	.516	.653	1.252	3.409	4.631	5.488	5.491	5.348
37.5	.309	.311	.144	.144	.171	.272	.198	.203	.338	.363	.474	.910	3.143	4.127	4.667	4.585	4.554
35.0	.266	.263	.133	.114	.133	.240	.178	.181	.238	.210	.296	.569	2.877	3.622	3.846	3.678	3.759
34.0	.258	.256	.132	.111	.134	.227	.175	.178	.227	.195	.263	.532	2.689	3.540	3.649	3.390	3.455
33.0	.250	.250	.132	.107	.135	.214	.172	.174	.216	.180	.230	.496	2.502	3.458	3.453	3.102	3.151
32.0	.242	.243	.131	.104	.136	.201	.169	.170	.205	.165	.197	.459	2.313	3.376	3.256	2.814	2.847
31.0	.234	.237	.130	.100	.138	.189	.165	.167	.194	.150	.164	.423	2.126	3.294	3.059	2.526	2.543
30.0	.225	.230	.130	.096	.139	.176	.162	.163	.183	.135	.132	.386	1.938	3.212	2.863	2.238	2.239
29.0	.206	.208	.133	.110	.147	.180	.166	.164	.199	.154	.148	.396	1.832	3.073	2.886	2.406	2.369
28.0	.186	.186	.136	.124	.155	.184	.171	.164	.214	.173	.163	.405	1.725	2.934	2.909	2.574	2.498
27.0	.166	.164	.140	.138	.163	.187	.176	.164	.229	.191	.179	.414	1.619	2.796	2.931	2.742	2.627
26.0	.147	.141	.143	.152	.171	.191	.180	.165	.245	.210	.194	.423	1.513	2.657	2.954	2.909	2.756
25.0	.127	.119	.147	.166	.180	.195	.184	.165	.260	.228	.210	.432	1.407	2.518	2.977	3.077	2.885
24.0	.107	.097	.150	.180	.188	.199	.189	.166	.275	.247	.226	.441	1.301	2.380	3.000	3.244	3.014
23.0	.087	.074	.153	.195	.196	.203	.194	.167	.291	.266	.241	.451	1.194	2.241	3.023	3.412	3.144
22.0	.067	.052	.157	.208	.204	.207	.198	.167	.306	.284	.256	.460	1.088	2.102	3.046	3.580	3.273
21.0	.047	.030	.160	.223	.212	.211	.203	.168	.321	.303	.272	.469	.982	1.963	3.069	3.748	3.402
20.0	.028	.008	.163	.237	.220	.215	.208	.168	.337	.321	.288	.478	.876	1.825	3.092	3.916	3.531
19.0	.046	.056	.208	.321	.344	.326	.270	.210	.418	.457	.505	.767	1.056	1.868	3.003	3.714	3.343
18.0	.066	.104	.254	.405	.468	.436	.333	.253	.498	.592	.723	1.056	1.237	1.912	2.913	3.513	3.155
17.0	.085	.153	.299	.489	.592	.547	.395	.296	.579	.727	.940	1.345	1.417	1.955	2.824	3.311	2.967
16.0	.129	.229	.391	.639	.771	.670	.461	.338	.667	.865	1.206	1.740	1.705	2.094	2.797	3.152	2.810
15.0	.275	.417	.671	1.048	1.171	.845	.537	.376	.783	1.015	1.664	2.561	2.423	2.615	3.019	3.160	2.776
14.0	.421	.606	.951	1.458	1.570	1.020	.614	.414	.900	1.165	2.122	3.383	3.139	3.137	3.240	3.169	2.743
13.0	.567	.794	1.232	1.868	1.970	1.195	.690	.452	1.016	1.315	2.580	4.204	3.856	3.658	3.461	3.178	2.709
12.0	.713	.982	1.512	2.277	2.370	1.369	.767	.491	1.133	1.465	3.038	5.025	4.573	4.179	3.682	3.187	2.676
10.0	1.634	1.930	2.396	2.709	2.124	1.042	.506	.325	.848	1.210	2.555	4.694	5.794	5.901	5.061	4.151	3.493
8.0	1.715	1.990	2.264	2.254	1.496	.676	.303	.197	.550	.848	1.793	3.514	5.296	5.899	5.190	4.394	3.773
6.0	1.116	1.299	1.417	1.374	.904	.460	.230	.164	.325	.512	1.074	2.211	3.493	4.187	3.862	3.410	2.966
4.0	.702	.804	.904	.900	.610	.393	.228	.156	.233	.330	.662	1.463	2.183	2.701	2.543	2.216	1.943
2.0	.495	.511	.577	.613	.454	.339	.233	.154	.204	.242	.428	.969	1.424	1.724	1.632	1.378	1.241
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

V (IN UNITS OF .001 KM/SEC)   FOR   JANUARY

				SOUTH				LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	.091	.134	.144	.133	.065	-.032	-.057	-.016	.021	.028	.034	-.057	-.143	-.136	-.132	-.128	-.104
47.5	.147	.261	.300	.328	.381	.539	.766	.986	1.103	1.095	.906	.540	.297	.236	.182	.088	-.057
45.0	.267	.451	.600	.757	.954	1.164	1.325	1.379	1.339	1.230	1.018	.709	.415	.272	.244	.240	.246
42.5	.250	.438	.622	.837	1.085	1.280	1.387	1.372	1.273	1.139	.959	.682	.306	.058	.038	.144	.268
40.0	.169	.318	.456	.640	.820	.923	.958	.910	.825	.738	.614	.442	.143	-.175	-.219	.026	.299
37.5	.119	.205	.295	.389	.443	.456	.438	.374	.335	.296	.246	.217	.101	-.237	-.363	-.022	.491
35.0	.084	.126	.179	.179	.114	.059	.022	-.016	-.011	-.010	-.004	.040	.054	-.243	-.475	-.221	.321
34.0	.069	.102	.141	.107	.008	-.064	-.102	-.118	-.096	-.079	-.050	.016	.056	-.227	-.498	-.304	.187
33.0	.037	.083	.103	.028	-.089	-.165	-.189	-.176	-.134	-.100	-.049	.039	.083	-.181	-.465	-.318	.162
32.0	.010	.054	.060	-.046	-.169	-.244	-.248	-.210	-.141	-.090	-.021	.076	.114	-.122	-.398	-.264	.254
31.0	-.001	.027	.010	-.101	-.222	-.293	-.287	-.228	-.137	-.066	.015	.111	.128	-.106	-.386	-.308	.102
30.0	-.010	.019	-.013	-.126	-.237	-.305	-.297	-.230	-.118	-.028	.060	.137	.131	-.082	-.354	-.305	.053
29.0	-.007	.026	-.009	-.125	-.229	-.296	-.293	-.224	-.103	-.002	.091	.144	.130	-.044	-.285	-.233	.145
28.0	.008	.044	.004	-.120	-.218	-.279	-.286	-.219	-.101	-.001	.092	.123	.108	-.035	-.256	-.215	.122
27.0	.033	.068	.020	-.114	-.208	-.259	-.273	-.205	-.099	-.010	.078	.093	.089	-.019	-.209	-.162	.161
26.0	.053	.083	.032	-.109	-.196	-.235	-.251	-.179	-.090	-.019	.056	.065	.075	-.013	-.182	-.136	.140
25.0	.062	.084	.033	-.100	-.177	-.202	-.217	-.139	-.063	-.015	.038	.046	.066	-.018	-.171	-.126	.108
24.0	.060	.078	.033	-.077	-.140	-.156	-.166	-.085	-.019	.006	.031	.039	.054	-.026	-.158	-.096	.144
23.0	.050	.074	.043	-.037	-.081	-.094	-.099	-.025	.030	.035	.033	.035	.030	-.056	-.165	-.096	.116
22.0	.044	.085	.069	.015	-.014	-.029	-.033	.028	.073	.067	.047	.038	.003	-.082	-.152	-.076	.097
21.0	.044	.108	.109	.065	.042	.023	.014	.058	.106	.105	.074	.046	-.023	-.100	-.122	-.041	.089
20.0	.046	.131	.142	.096	.075	.047	.024	.060	.129	.151	.115	.061	-.038	-.108	-.093	-.017	.057
19.0	.042	.135	.153	.102	.087	.049	-.006	.034	.152	.212	.165	.080	-.038	-.105	-.063	.013	.059
18.0	.033	.116	.135	.087	.100	.036	-.090	-.013	.235	.344	.214	.083	-.026	-.081	-.032	.031	.059
17.0	.008	.074	.101	.085	.113	.024	-.092	.039	.462	.681	.363	.047	-.088	-.135	-.077	-.011	-.005
16.0	-.034	.017	.068	.109	.106	.027	.053	.243	.830	1.223	.650	-.020	-.263	-.320	-.222	-.121	-.184
15.0	-.064	-.029	.045	.134	.079	.038	.224	.499	1.243	1.769	.960	-.054	-.427	-.492	-.320	-.176	-.342
14.0	-.075	-.054	.023	.133	.049	.036	.291	.677	1.549	2.065	1.144	-.020	-.463	-.511	-.255	-.076	-.276
13.0	-.077	-.062	-.000	.104	.038	.011	.218	.686	1.605	1.948	1.075	.009	-.419	-.427	-.135	.042	-.134
12.0	-.082	-.063	-.022	.075	.046	-.032	.112	.571	1.391	1.531	.820	-.027	-.392	-.370	-.114	.045	-.042
10.0	-.075	-.045	-.033	.062	.056	-.072	.004	.296	.680	.687	.360	-.098	-.329	-.340	-.178	-.021	.028
8.0	-.042	-.020	-.017	.045	.044	-.041	-.077	.027	.075	.161	.121	-.047	-.160	-.226	-.115	-.003	-.030
6.0	.001	-.007	.001	-.004	.005	-.003	-.125	-.204	-.289	-.132	.004	.032	.009	-.032	.012	.032	-.034
4.0	.032	.000	.003	-.042	-.029	.013	-.072	-.268	-.486	-.432	-.174	.062	.146	.156	.094	.034	.042
2.0	.032	.006	-.020	-.065	-.052	.026	.035	-.162	-.548	-.789	-.481	-.000	.221	.267	.129	.008	.034
0.0	.008	.003	-.056	-.087	-.066	.082	.369	.573	.236	-.206	-.247	-.036	.134	.206	.103	.004	-.052

W (IN UNITS OF .000001 KM/SEC)   FOR JANUARY

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	NORTH 10	20	30	40	50	60	70	80
50.0	5.120	3.150	2.310	2.390	2.740	2.730	2.180	1.310	.435	-.945	-1.540	-2.390	-3.970	-4.290	-5.610	-7.170	-7.730
47.5	4.035	2.485	1.640	1.680	2.075	2.415	2.220	1.595	.557	-.799	-1.775	-2.655	-3.220	-3.085	-4.195	-5.220	-5.740
45.0	3.720	2.390	1.610	1.600	1.900	2.210	1.990	1.330	.385	-.882	-1.900	-2.640	-2.680	-2.450	-3.200	-3.960	[illegible]
42.5	3.670	2.520	1.905	1.890	2.085	2.100	1.685	.908	.036	-1.012	-1.950	-2.705	-2.640	-2.030	-2.325	-2.875	[illegible]
40.0	3.370	2.470	2.050	2.070	2.130	1.860	1.340	.559	-.214	-1.010	-1.870	-2.640	-2.680	-1.670	-1.330	-1.700	-2.310
37.5	2.865	2.185	1.890	1.935	1.810	1.440	.946	.269	-.265	-.859	-1.560	-2.190	-2.420	-1.570	-.392	-.453	-1.755
35.0	2.350	1.790	1.580	1.520	1.290	.982	.599	.083	-.199	-.648	-1.120	-1.520	-1.940	-1.680	.154	.710	-1.290
34.0	2.150	1.630	1.430	1.300	1.050	.805	.486	.055	-.152	-.551	-.932	-1.260	-1.730	-1.710	.232	1.070	-1.030
33.0	1.940	1.480	1.260	1.060	.816	.645	.398	.055	-.099	-.453	-.746	-1.020	-1.530	-1.730	.248	1.350	-.748
32.0	1.730	1.330	1.080	.810	.598	.505	.343	.078	-.037	-.354	-.573	-.809	-1.360	-1.740	.223	1.550	-.466
31.0	1.520	1.180	.892	.574	.406	.386	.314	.118	.035	-.254	-.416	-.636	-1.230	-1.730	.170	1.680	-.215
30.0	1.320	1.030	.709	.365	.242	.283	.296	.167	.116	-.156	-.281	-.504	-1.130	-1.710	.102	1.760	-.013
29.0	1.140	.900	.543	.187	.107	.193	.281	.217	.201	-.062	-.172	-.415	-1.050	-1.660	.028	1.790	.138
28.0	.996	.791	.396	.034	.000	.113	.261	.261	.278	.022	-.084	-.360	-.965	-1.590	-.045	1.780	.236
27.0	.899	.702	.268	-.099	-.083	.048	.233	.299	.332	.090	-.015	-.327	-.867	-1.500	-.108	1.740	.286
26.0	.844	.628	.155	-.218	-.145	-.000	.203	.332	.360	.141	.040	-.301	-.758	-1.400	-.156	1.680	.295
25.0	.812	.563	.060	-.317	-.188	-.030	.174	.362	.361	.168	.077	-.271	-.649	-1.310	-.187	1.600	.275
24.0	.785	.502	-.015	-.386	-.213	-.046	.152	.390	.345	.169	.094	-.235	-.554	-1.230	-.199	1.530	.242
23.0	.753	.451	-.062	-.417	-.219	-.052	.139	.409	.317	.147	.089	-.200	-.486	-1.140	-.191	1.470	.206
22.0	.718	.421	-.081	-.409	-.210	-.053	.131	.412	.283	.109	.066	-.175	-.449	-1.050	-.158	1.410	.172
21.0	.695	.421	-.073	-.377	-.190	-.054	.124	.399	.252	.070	.031	-.168	-.439	-.938	-.098	1.330	.143
20.0	.688	.451	-.048	-.340	-.165	-.061	.111	.379	.241	.039	-.013	-.188	-.449	-.612	-.021	1.230	.116
19.0	.692	.495	-.018	-.309	-.143	-.078	.088	.371	.262	.026	-.070	-.232	-.467	-.686	.062	1.110	.092
18.0	.685	.531	.009	-.284	-.117	-.114	.039	.396	.330	.028	-.153	-.292	-.489	-.572	.144	.991	.074
17.0	.658	.539	.030	-.249	-.078	-.211	-.047	.530	.523	-.019	-.352	-.335	-.482	-.479	.191	.862	.074
16.0	.578	.525	.067	-.189	-.062	-.272	-.024	.713	.864	-.052	-.842	-.536	-.441	-.374	.297	.800	.105
15.0	.453	.497	.126	-.111	-.089	-.238	.159	.941	1.350	-.060	-1.670	-.971	-.380	-.229	.504	.795	.141
14.0	.315	.459	.193	-.035	-.148	-.121	.448	1.240	1.910	-.095	-2.670	-1.560	-.330	-.053	.785	.776	.146
13.0	.187	.413	.242	.029	-.208	-.006	.734	1.630	2.440	-.242	-3.560	-2.130	-.305	.134	1.040	.691	.108
12.0	.076	.364	.262	.082	-.242	.024	.935	2.040	2.830	-.531	-4.110	-2.530	-.295	.315	1.200	.574	.059
10.0	-.115	.286	.251	.192	-.287	-.107	1.200	2.480	3.060	-1.090	-4.300	-2.870	-.250	.588	1.300	.561	.076
8.0	-.207	.251	.229	.289	-.337	-.237	1.200	2.330	2.610	-.999	-3.840	-2.750	-.243	.586	1.420	.652	.137
6.0	-.207	.211	.198	.295	-.305	-.315	.829	1.960	2.060	-.507	-3.140	-2.310	-.278	.432	1.390	.499	.105
4.0	-.136	.140	.168	.174	-.198	-.302	.357	1.360	1.640	.025	-2.320	-1.790	-.263	.316	1.070	.307	.059
2.0	-.050	.061	.111	.069	-.096	-.201	.075	.643	.973	.263	-1.230	-1.010	-.182	.148	.533	.162	.025
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

T (IN UNITS OF 100. DEGREES KELVIN) FOR APRIL

	SOUTH							LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	2.638	2.657	2.676	2.696	2.715	2.724	2.723	2.721	2.715	2.695	2.672	2.661	2.662	2.673	2.673	2.709	2.754
47.5	2.573	2.598	2.627	2.655	2.679	2.697	2.703	2.704	2.700	2.699	2.682	2.675	2.665	2.655	2.649	2.679	2.719
45.0	2.509	2.535	2.571	2.604	2.633	2.654	2.664	2.668	2.667	2.670	2.659	2.651	2.636	2.614	2.610	2.637	2.673
42.5	2.446	2.474	2.511	2.544	2.573	2.598	2.612	2.619	2.620	2.622	2.613	2.602	2.582	2.561	2.560	2.586	2.618
40.0	2.381	2.410	2.449	2.484	2.515	2.540	2.556	2.564	2.567	2.567	2.559	2.545	2.526	2.504	2.505	2.530	2.560
37.5	2.320	2.348	2.386	2.423	2.455	2.482	2.498	2.508	2.510	2.510	2.502	2.488	2.469	2.447	2.448	2.473	2.500
35.0	2.263	2.288	2.324	2.362	2.396	2.425	2.442	2.451	2.452	2.450	2.442	2.430	2.411	2.391	2.393	2.415	2.440
34.0	2.243	2.266	2.301	2.338	2.372	2.401	2.420	2.427	2.429	2.425	2.418	2.405	2.389	2.371	2.372	2.392	2.419
33.0	2.223	2.246	2.279	2.314	2.349	2.378	2.396	2.403	2.405	2.401	2.394	2.382	2.367	2.351	2.351	2.371	2.397
32.0	2.205	2.227	2.259	2.292	2.325	2.355	2.373	2.379	2.382	2.377	2.370	2.359	2.344	2.332	2.331	2.348	2.373
31.0	2.188	2.210	2.240	2.271	2.302	2.332	2.351	2.356	2.358	2.352	2.348	2.335	2.323	2.314	2.313	2.328	2.352
30.0	2.172	2.194	2.223	2.250	2.280	2.309	2.327	2.332	2.334	2.329	2.324	2.312	2.303	2.296	2.296	2.309	2.332
29.0	2.157	2.179	2.208	2.232	2.258	2.285	2.304	2.306	2.309	2.306	2.301	2.290	2.285	2.280	2.281	2.292	2.314
28.0	2.144	2.167	2.195	2.216	2.237	2.263	2.279	2.282	2.285	2.282	2.278	2.269	2.267	2.267	2.268	2.277	2.298
27.0	2.132	2.157	2.185	2.202	2.217	2.239	2.256	2.258	2.259	2.257	2.255	2.248	2.251	2.254	2.256	2.265	2.286
26.0	2.121	2.148	2.176	2.190	2.200	2.217	2.231	2.233	2.233	2.231	2.231	2.227	2.235	2.241	2.243	2.254	2.276
25.0	2.112	2.141	2.168	2.180	2.185	2.195	2.205	2.206	2.206	2.204	2.206	2.206	2.221	2.230	2.232	2.245	2.268
24.0	2.104	2.134	2.163	2.173	2.173	2.174	2.178	2.178	2.177	2.177	2.181	2.185	2.207	2.220	2.225	2.237	2.260
23.0	2.099	2.130	2.159	2.169	2.163	2.154	2.151	2.149	2.149	2.150	2.154	2.165	2.195	2.212	2.219	2.232	2.254
22.0	2.097	2.128	2.158	2.166	2.155	2.135	2.123	2.119	2.117	2.119	2.126	2.147	2.185	2.205	2.215	2.229	2.249
21.0	2.100	2.131	2.159	2.166	2.150	2.117	2.095	2.086	2.082	2.085	2.097	2.130	2.177	2.200	2.211	2.227	2.246
20.0	2.107	2.136	2.163	2.168	2.145	2.100	2.064	2.047	2.044	2.049	2.067	2.111	2.168	2.196	2.208	2.226	2.245
19.0	2.117	2.145	2.170	2.172	2.141	2.085	2.035	2.007	2.002	2.012	2.037	2.092	2.158	2.193	2.208	2.227	2.244
18.0	2.131	2.158	2.181	2.177	2.139	2.073	2.011	1.972	1.962	1.979	2.012	2.074	2.147	2.189	2.207	2.228	2.245
17.0	2.148	2.174	2.191	2.180	2.135	2.063	1.998	1.954	1.943	1.964	1.998	2.061	2.137	2.185	2.206	2.227	2.245
16.0	2.167	2.190	2.201	2.183	2.132	2.060	2.004	1.973	1.968	1.985	2.012	2.062	2.132	2.182	2.207	2.227	2.243
15.0	2.183	2.204	2.209	2.184	2.134	2.076	2.042	2.032	2.031	2.040	2.056	2.086	2.137	2.180	2.206	2.225	2.240
14.0	2.195	2.212	2.211	2.183	2.142	2.112	2.108	2.109	2.110	2.114	2.120	2.127	2.150	2.180	2.204	2.222	2.235
13.0	2.200	2.214	2.209	2.182	2.161	2.164	2.182	2.188	2.189	2.192	2.191	2.179	2.174	2.183	2.202	2.217	2.230
12.0	2.195	2.211	2.205	2.186	2.193	2.223	2.252	2.260	2.263	2.266	2.262	2.239	2.207	2.194	2.201	2.213	2.226
10.0	2.179	2.194	2.211	2.249	2.303	2.351	2.383	2.396	2.402	2.403	2.396	2.366	2.310	2.250	2.217	2.217	2.226
8.0	2.202	2.232	2.291	2.373	2.438	2.484	2.518	2.532	2.536	2.534	2.523	2.490	2.430	2.351	2.285	2.255	2.249
6.0	2.296	2.347	2.420	2.499	2.563	2.612	2.646	2.660	2.664	2.660	2.646	2.613	2.550	2.473	2.406	2.362	2.337
4.0	2.406	2.459	2.533	2.610	2.678	2.730	2.764	2.777	2.781	2.777	2.760	2.722	2.661	2.589	2.524	2.475	2.445
2.0	2.502	2.554	2.627	2.705	2.774	2.828	2.864	2.878	2.883	2.880	2.859	2.816	2.757	2.693	2.630	2.577	2.542
0.0	2.577	2.630	2.701	2.779	2.850	2.911	2.952	2.965	2.973	2.971	2.946	2.897	2.838	2.780	2.711	2.641	2.587

KZZ (IN UNITS OF .00001 KMSQ/SEC) FOR APRIL

	SOUTH							LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	3.006	1.239	2.393	6.191	2.642	.536	.190	.215	.311	.335	.251	1.100	3.742	2.769	3.997	3.372	2.115
47.5	2.572	1.060	2.048	5.298	2.261	.458	.162	.184	.266	.286	.214	.941	3.202	2.370	3.420	2.886	1.810
45.0	2.139	.882	1.703	4.405	1.880	.381	.135	.153	.221	.238	.178	.783	2.663	1.971	2.844	2.400	1.505
42.5	1.705	.703	1.357	3.512	1.499	.304	.108	.122	.177	.190	.142	.624	2.123	1.571	2.267	1.913	1.200
40.0	1.272	.524	1.012	2.619	1.118	.227	.080	.091	.132	.142	.106	.465	1.583	1.172	1.691	1.427	.895
37.5	1.084	.447	.863	2.233	.953	.193	.068	.077	.112	.121	.090	.397	1.349	.999	1.441	1.216	.763
35.0	.896	.369	.713	1.846	.788	.160	.057	.064	.093	.100	.075	.328	1.116	.826	1.191	1.005	.630
34.0	.821	.338	.654	1.691	.722	.146	.052	.059	.085	.091	.068	.300	1.022	.756	1.092	.921	.578
33.0	.746	.307	.594	1.536	.656	.133	.047	.053	.077	.083	.062	.273	.928	.687	.992	.837	.525
32.0	.671	.276	.534	1.381	.590	.120	.042	.048	.069	.075	.056	.245	.835	.618	.892	.752	.472
31.0	.596	.245	.474	1.227	.524	.106	.038	.043	.062	.066	.050	.218	.741	.549	.792	.668	.419
30.0	.520	.215	.414	1.072	.457	.093	.033	.037	.054	.058	.043	.190	.648	.479	.692	.584	.366
29.0	.476	.196	.379	.981	.419	.085	.030	.034	.049	.053	.040	.174	.593	.439	.633	.534	.335
28.0	.432	.178	.344	.890	.380	.077	.027	.031	.045	.048	.036	.158	.538	.398	.574	.485	.304
27.0	.388	.160	.309	.799	.341	.069	.024	.028	.040	.043	.032	.142	.483	.357	.516	.435	.273
26.0	.344	.142	.274	.708	.302	.061	.022	.025	.036	.038	.029	.126	.428	.317	.457	.386	.242
25.0	.299	.123	.238	.617	.263	.053	.019	.021	.031	.033	.025	.110	.373	.276	.398	.336	.211
24.0	.255	.105	.203	.526	.224	.045	.016	.018	.026	.028	.021	.093	.318	.235	.339	.286	.180
23.0	.211	.087	.168	.435	.186	.038	.013	.015	.022	.024	.018	.077	.263	.195	.281	.237	.149
22.0	.167	.069	.133	.344	.147	.030	.011	.012	.017	.019	.014	.061	.208	.154	.222	.187	.117
21.0	.123	.051	.098	.253	.108	.022	.008	.009	.013	.014	.010	.045	.153	.113	.163	.138	.086
20.0	.079	.032	.063	.162	.069	.014	.005	.006	.008	.009	.007	.029	.098	.072	.105	.088	.055
19.0	.080	.080	.080	.157	.095	.034	.014	.009	.010	.013	.022	.069	.117	.083	.097	.097	.097
18.0	.098	.098	.098	.152	.122	.054	.023	.012	.012	.017	.038	.110	.137	.094	.089	.089	.089
17.0	.115	.115	.115	.147	.148	.075	.031	.015	.014	.021	.054	.150	.156	.105	.081	.081	.081
16.0	.129	.129	.129	.146	.172	.092	.040	.018	.018	.025	.067	.179	.172	.117	.080	.080	.080
15.0	.127	.127	.127	.161	.160	.088	.050	.019	.028	.031	.065	.157	.172	.133	.102	.102	.102
14.0	.125	.125	.125	.175	.147	.084	.060	.020	.038	.036	.063	.135	.172	.150	.125	.125	.125
13.0	.123	.123	.123	.189	.135	.080	.070	.023	.049	.045	.061	.112	.173	.167	.147	.147	.147
12.0	.058	.060	.121	.203	.122	.076	.089	.032	.063	.058	.078	.137	.173	.184	.168	.166	.165
10.0	.080	.089	.129	.195	.340	.124	.142	.061	.105	.100	.128	.204	.289	.136	.104	.103	.103
8.0	.105	.114	.153	.329	.462	.203	.227	.116	.177	.172	.209	.304	.403	.162	.119	.118	.118
6.0	.113	.127	.205	.479	.614	.334	.364	.220	.299	.295	.342	.454	.560	.284	.170	.091	.086
4.0	.219	.288	.397	.700	.822	.550	.582	.418	.508	.507	.561	.677	.779	.497	.344	.230	.204
2.0	.573	.657	.772	1.023	1.107	.908	.934	.792	.870	.872	.917	1.008	1.081	.865	.709	.586	.551
0.0	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500

KFZ (IN UNITS OF .001 KMSQ/SEC) FOR APRIL

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	10	20	30	40	NORTH 50	60	70	80
50.0	.358	.814	1.085	1.078	1.294	.324	.021	-.005	-.036	-.093	-.065	-.355	-.925	-.825	-.825	-.619	-.272
47.5	.425	.966	1.288	1.280	1.294	.324	.021	-.005	-.036	-.097	-.065	-.355	-.925	-.825	-.825	-.619	-.272
45.0	.492	1.118	1.491	1.482	1.473	.356	.021	-.006	-.036	-.101	-.066	-.372	-1.010	-.928	-.928	-.696	-.306
42.5	.497	1.129	1.506	1.497	1.409	.328	.017	-.005	-.033	-.094	-.058	-.329	-1.031	-.965	-.965	-.724	-.318
40.0	.502	1.140	1.520	1.511	1.346	.301	.013	-.005	-.031	-.087	-.051	-.287	-1.052	-1.001	-1.001	-.751	-.330
37.5	.467	1.060	1.414	1.405	1.311	.236	.011	-.004	-.027	-.080	-.048	-.256	-1.114	-1.021	-1.021	-.766	-.337
35.0	.431	.981	1.307	1.298	1.275	.171	.008	-.003	-.023	-.073	-.044	-.224	-1.176	-1.041	-1.041	-.781	-.344
34.0	.432	.982	1.309	1.300	1.226	.157	.007	-.003	-.023	-.074	-.044	-.228	-1.145	-1.054	-1.054	-.790	-.348
33.0	.433	.983	1.311	1.301	1.177	.142	.006	-.003	-.022	-.075	-.044	-.231	-1.114	-1.067	-1.067	-.800	-.352
32.0	.433	.985	1.313	1.303	1.128	.128	.006	-.003	-.022	-.077	-.044	-.235	-1.083	-1.079	-1.079	-.810	-.356
31.0	.434	.986	1.315	1.305	1.079	.114	.005	-.003	-.022	-.078	-.044	-.238	-1.052	-1.092	-1.092	-.819	-.360
30.0	.434	.987	1.316	1.307	1.029	.099	.004	-.003	-.022	-.079	-.044	-.241	-1.020	-1.105	-1.105	-.829	-.365
29.0	.433	.985	1.313	1.303	.987	.107	.005	-.003	-.025	-.081	-.046	-.251	-.997	-1.072	-1.072	-.804	-.354
28.0	.432	.982	1.309	1.300	.944	.115	.006	-.003	-.027	-.084	-.047	-.260	-.973	-1.039	-1.039	-.779	-.343
27.0	.431	.979	1.305	1.296	.902	.123	.007	-.003	-.030	-.086	-.049	-.269	-.949	-1.005	-1.005	-.754	-.332
26.0	.429	.976	1.301	1.293	.860	.131	.008	-.004	-.033	-.088	-.050	-.278	-.925	-.972	-.972	-.729	-.321
25.0	.428	.973	1.298	1.289	.817	.139	.009	-.004	-.035	-.091	-.052	-.287	-.901	-.939	-.939	-.704	-.310
24.0	.425	.966	1.289	1.280	.775	.147	.009	-.004	-.038	-.093	-.053	-.296	-.878	-.932	-.932	-.699	-.307
23.0	.422	.960	1.280	1.272	.732	.155	.010	-.004	-.041	-.095	-.055	-.305	-.854	-.924	-.924	-.693	-.305
22.0	.419	.953	1.271	1.263	.690	.163	.011	-.004	-.043	-.097	-.056	-.314	-.830	-.917	-.917	-.688	-.303
21.0	.416	.946	1.262	1.254	.647	.171	.012	-.004	-.046	-.100	-.058	-.323	-.806	-.910	-.910	-.683	-.300
20.0	.413	.940	1.253	1.246	.605	.179	.013	-.004	-.049	-.102	-.059	-.332	-.783	-.903	-.903	-.677	-.298
19.0	.426	.969	1.292	1.284	.828	.393	.110	.037	-.062	-.144	-.218	-.693	-.985	-.971	-.971	-.728	-.320
18.0	.439	.999	1.332	1.323	1.050	.607	.208	.079	-.075	-.186	-.376	-1.053	-1.188	-1.040	-1.040	-.780	-.343
17.0	.452	1.028	1.371	1.361	1.273	.821	.305	.120	-.088	-.228	-.534	-1.413	-1.391	-1.108	-1.108	-.831	-.366
16.0	.472	1.072	1.429	1.418	1.438	.942	.373	.142	-.093	-.241	-.621	-1.583	-1.581	-1.205	-1.205	-.903	-.398
15.0	.544	1.236	1.648	1.636	1.373	.666	.321	.083	-.052	-.136	-.425	-.948	-1.720	-1.544	-1.544	-1.158	-.509
14.0	.618	1.405	1.874	1.859	1.309	.410	.270	.017	-.023	-.044	-.229	-.363	-1.859	-1.891	-1.891	-1.419	-.624
13.0	.693	1.575	2.100	2.083	1.244	.214	.213	-.053	.007	.010	-.038	.100	-1.999	-2.247	-2.247	-1.685	-.742
12.0	.768	1.746	2.328	2.307	1.179	.135	.156	-.100	.016	.040	.083	.100	-2.138	-2.612	-2.612	-1.959	-.862
10.0	-.100	-.100	-.100	-.100	-.100	-.100	-.100	-.088	.009	.100	.100	.100	.100	.099	-.340	-.069	.060
8.0	-.100	-.100	-.100	-.100	-.100	-.100	-.100	-.056	-.005	.100	.100	.100	.100	.100	.100	.066	.100
6.0	.156	-.084	-.058	-.100	-.100	-.100	-.100	-.056	-.099	.078	.100	.100	.100	.100	.100	.015	-.055
4.0	.462	.705	1.372	.564	-.089	-.100	-.100	-.090	-.006	.045	.100	.100	.100	-.963	-1.116	-.499	-.462
2.0	.686	1.117	2.168	1.931	.785	.120	-.098	-.079	.050	.100	.100	-.381	-1.213	-2.002	-1.943	-.957	-.563
0.0	.513	.829	1.688	1.694	.903	.490	-.031	-.094	.021	.081	-.052	-.766	-1.190	-1.716	-1.575	-.770	-.412

KFF (IN UNITS OF KMSQ/SEC) FOR APRIL

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	NORTH 10	20	30	40	50	60	70	80
50.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47.5	4.974	4.955	3.962	2.781	3.243	1.746	.982	.542	.757	.880	1.071	1.320	2.049	2.992	3.417	3.191	3.807
45.0	4.788	4.712	3.625	2.666	3.038	1.562	.813	.406	.609	.745	.861	1.114	1.821	2.765	3.175	2.726	3.088
42.5	4.607	4.504	3.036	2.347	2.559	1.274	.587	.329	.499	.613	.682	.881	1.623	2.504	2.891	2.222	2.481
40.0	4.425	4.296	2.448	2.029	2.081	.985	.362	.251	.388	.481	.503	.648	1.423	2.242	2.607	1.718	1.873
37.5	3.870	3.656	1.998	1.704	1.831	.718	.266	.190	.312	.400	.426	.534	1.347	2.054	2.282	1.435	1.558
35.0	3.315	3.015	1.549	1.378	1.580	.451	.171	.128	.236	.319	.350	.420	1.270	1.865	1.958	1.152	1.243
34.0	3.032	2.769	1.445	1.333	1.476	.405	.150	.119	.227	.312	.338	.412	1.201	1.823	1.874	1.082	1.171
33.0	2.748	2.524	1.341	1.288	1.373	.358	.129	.110	.218	.306	.327	.405	1.132	1.781	1.789	1.012	1.098
32.0	2.464	2.278	1.236	1.244	1.269	.312	.108	.100	.210	.300	.315	.397	1.062	1.738	1.705	.942	1.026
31.0	2.181	2.032	1.132	1.198	1.166	.265	.087	.091	.201	.294	.303	.390	.993	1.695	1.620	.873	.953
30.0	1.898	1.787	1.028	1.153	1.062	.219	.067	.082	.193	.287	.291	.382	.924	1.653	1.536	.802	.881
29.0	1.836	1.737	1.052	1.123	1.003	.227	.077	.094	.205	.286	.292	.383	.886	1.574	1.514	.914	.982
28.0	1.775	1.688	1.077	1.093	.943	.234	.088	.105	.218	.286	.292	.384	.848	1.495	1.493	1.025	1.084
27.0	1.713	1.638	1.101	1.062	.884	.242	.099	.117	.231	.284	.292	.385	.810	1.416	1.471	1.135	1.186
26.0	1.652	1.588	1.126	1.032	.824	.249	.109	.129	.244	.284	.293	.386	.772	1.337	1.450	1.247	1.288
25.0	1.591	1.538	1.150	1.002	.764	.256	.120	.141	.256	.283	.293	.388	.734	1.258	1.428	1.358	1.390
24.0	1.529	1.488	1.175	.971	.705	.264	.130	.153	.269	.282	.294	.389	.696	1.179	1.407	1.469	1.492
23.0	1.468	1.439	1.199	.941	.645	.271	.141	.165	.281	.281	.294	.390	.659	1.101	1.386	1.580	1.594
22.0	1.407	1.389	1.223	.911	.586	.279	.152	.177	.294	.280	.294	.391	.621	1.022	1.364	1.691	1.695
21.0	1.346	1.339	1.248	.881	.526	.286	.163	.189	.307	.279	.294	.392	.583	.943	1.343	1.802	1.797
20.0	1.284	1.289	1.272	.850	.467	.294	.174	.200	.319	.278	.294	.393	.545	.864	1.322	1.913	1.899
19.0	1.253	1.264	1.261	.946	.625	.440	.273	.255	.371	.373	.448	.624	.724	.958	1.379	1.879	1.785
18.0	1.222	1.239	1.249	1.042	.784	.586	.371	.310	.423	.468	.603	.853	.902	1.052	1.436	1.845	1.672
17.0	1.191	1.214	1.238	1.138	.943	.733	.470	.364	.475	.563	.757	1.084	1.081	1.147	1.494	1.812	1.558
16.0	1.193	1.228	1.295	1.325	1.182	.931	.590	.423	.528	.659	.947	1.387	1.345	1.316	1.588	1.797	1.468
15.0	1.332	1.400	1.627	1.880	1.742	1.337	.796	.495	.587	.756	1.283	1.986	1.951	1.788	1.827	1.861	1.477
14.0	1.471	1.573	1.959	2.435	2.303	1.742	1.002	.566	.645	.854	1.619	2.585	2.556	2.259	2.067	1.925	1.484
13.0	1.611	1.745	2.292	2.990	2.864	2.148	1.209	.639	.704	.952	1.955	3.184	3.162	2.730	2.307	1.990	1.493
12.0	1.750	1.917	2.624	3.546	3.424	2.554	1.415	.711	.763	1.049	2.291	3.783	3.767	3.202	2.546	2.054	1.501
10.0	2.669	2.780	3.628	4.362	3.658	2.233	1.088	.541	.567	.853	1.862	3.430	4.598	4.774	3.988	3.102	2.299
8.0	2.854	2.898	3.513	3.982	3.030	1.614	.725	.363	.386	.602	1.264	2.503	4.006	4.687	4.154	3.406	2.576
6.0	2.168	2.116	2.406	2.632	1.919	1.032	.465	.246	.254	.372	.762	1.591	2.601	3.197	2.979	2.603	1.994
4.0	1.378	1.328	1.554	1.667	1.201	.724	.347	.207	.190	.263	.500	1.110	1.679	2.055	1.919	1.633	1.280
2.0	.849	.837	1.042	1.063	.792	.527	.278	.182	.159	.205	.361	.779	1.128	1.315	1.187	.979	.641
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

V (IN UNITS OF .001 KM/SEC)   FOR   APRIL

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	10	20	30	40	NORTH 50	60	70	80
50.0	.091	.134	.144	.133	.065	-.032	-.057	-.016	.021	.028	.034	-.057	-.143	-.136	-.132	-.128	-.104
47.5	.167	.252	.446	.695	.801	.755	.639	.472	.257	.061	-.111	-.266	-.313	-.209	-.029	.024	-.107
45.0	.164	.207	.355	.522	.603	.567	.503	.402	.256	.101	-.017	-.122	-.159	-.089	.008	-.006	-.149
42.5	.180	.256	.340	.382	.342	.302	.280	.249	.177	.096	.056	.023	-.010	-.014	-.017	-.042	-.098
40.0	.190	.319	.371	.332	.227	.189	.182	.161	.105	.055	.032	.034	-.004	-.092	-.139	-.093	-.024
37.5	.191	.354	.417	.322	.217	.187	.175	.130	.055	-.005	-.042	-.046	-.091	-.236	-.296	-.174	.014
35.0	.170	.360	.446	.345	.229	.179	.151	.095	.030	-.032	-.067	-.078	-.128	-.285	-.378	-.247	-.012
34.0	.164	.338	.437	.350	.228	.163	.127	.079	.034	-.018	-.049	-.052	-.097	-.248	-.358	-.242	.033
33.0	.169	.325	.403	.345	.223	.142	.102	.066	.042	.005	-.022	-.014	-.047	-.192	-.323	-.232	.028
32.0	.158	.300	.357	.321	.213	.126	.080	.054	.052	.031	.011	.029	.008	-.131	-.270	-.208	.021
31.0	.135	.270	.320	.300	.209	.124	.075	.055	.073	.066	.057	.077	.059	-.072	-.207	-.155	.057
30.0	.101	.232	.283	.273	.198	.125	.075	.060	.090	.095	.099	.108	.083	-.038	-.159	-.112	.066
29.0	.081	.199	.256	.247	.186	.120	.076	.070	.108	.122	.139	.132	.095	-.013	-.110	-.064	.082
28.0	.063	.177	.238	.223	.169	.104	.072	.081	.121	.139	.167	.147	.103	.010	-.065	-.021	.098
27.0	.052	.165	.221	.197	.145	.074	.055	.080	.117	.137	.172	.146	.101	.022	-.041	.005	.112
26.0	.055	.166	.212	.179	.121	.042	.031	.070	.102	.122	.155	.134	.097	.034	-.021	.032	.158
25.0	.062	.165	.198	.158	.093	.013	-.001	.043	.072	.091	.114	.101	.080	.031	-.018	.042	.183
24.0	.072	.166	.186	.138	.070	.000	-.026	.012	.038	.055	.061	.056	.049	.010	-.033	.033	.172
23.0	.074	.166	.178	.121	.058	.004	-.035	-.014	.013	.029	.016	.013	.021	-.012	-.043	.028	.159
22.0	.065	.156	.163	.100	.050	.012	-.037	-.030	.000	.019	-.009	-.019	-.004	-.028	-.045	.028	.142
21.0	.052	.140	.142	.075	.044	.015	-.037	-.039	.002	.028	-.008	-.032	-.016	-.033	-.035	.035	.127
20.0	.026	.119	.119	.051	.045	.023	-.037	-.046	.014	.053	.009	-.035	-.024	-.034	-.020	.041	.098
19.0	-.008	.104	.110	.050	.075	.051	-.046	-.038	.035	.104	.047	-.026	-.031	-.030	.008	.073	.130
18.0	-.047	.090	.110	.065	.108	.048	-.144	-.279	.049	.234	.131	-.021	-.077	-.095	-.062	-.036	-.109
17.0	-.067	.055	.086	.063	.094	.007	-.338	-.486	.078	.379	.226	.021	-.034	-.021	.047	.108	.168
16.0	-.055	-.004	.029	.035	.035	-.024	-.532	-.530	.146	.454	.281	.057	.071	.194	.355	.548	1.050
15.0	-.027	-.057	-.026	.002	-.028	-.031	-.652	-.451	.226	.472	.214	-.086	-.036	.146	.321	.494	.955
14.0	-.008	-.077	-.046	-.007	-.052	-.015	-.663	-.348	.311	.478	.170	-.167	-.117	.079	.267	.434	.831
13.0	-.008	-.058	-.025	.021	-.027	.003	-.603	-.322	.356	.486	.177	-.150	-.152	.001	.195	.361	.669
12.0	-.016	-.032	-.002	.054	.004	-.003	-.516	-.316	.333	.461	.111	-.229	-.325	-.266	-.156	-.154	-.369
10.0	-.023	-.019	.005	.079	.030	-.033	-.301	-.174	.215	.250	.017	-.181	-.319	-.302	-.233	-.289	-.639
8.0	-.033	-.026	.004	.065	.033	-.046	-.119	-.065	.045	.040	-.004	-.023	-.127	-.099	-.004	.024	-.023
6.0	-.030	-.017	.001	.011	.013	-.033	-.029	-.048	-.102	-.047	-.007	.019	-.057	-.036	.017	.030	.021
4.0	-.001	-.002	-.009	-.040	-.016	.000	.084	.034	-.142	-.115	-.018	.056	.069	.062	.032	.024	.061
2.0	.026	.000	-.035	-.072	-.042	.026	.340	.250	-.121	-.252	-.081	.091	.193	.136	.033	-.003	.033
0.0	.008	.003	-.056	-.087	-.066	.082	.369	.573	.236	-.206	-.247	-.036	.134	.206	.103	.004	-.052

W (IN UNITS OF .000001 KM/SEC) FOR APRIL

	SOUTH						LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	-.455	-.116	.106	-.030	-.341	-.431	-.538	-.613	-.327	.028	.429	.869	.918	.794	.368	-.541	-1.390
47.5	.350	.627	.919	.694	.035	-.337	-.640	-.816	-.705	-.293	.010	.451	.819	1.011	.651	-.374	-1.150
45.0	.721	.836	1.410	1.230	.387	-.251	-.603	-.902	-.873	-.564	-.269	.140	.712	1.070	.719	-.400	-.930
42.5	.993	.979	1.475	1.235	.433	-.170	-.463	-.791	-.847	-.616	-.320	-.009	.535	.690	.533	-.407	-.669
40.0	1.310	1.120	1.340	.956	.210	-.106	-.319	-.585	-.702	-.506	-.238	-.050	.280	.555	.331	-.250	-.436
37.5	1.565	1.295	1.175	.648	.049	-.044	-.230	-.489	-.616	-.418	-.195	-.028	.056	.216	.366	.156	-.213
35.0	1.750	1.470	1.080	.353	-.014	-.016	-.193	-.473	-.573	-.389	-.181	-.034	-.093	-.055	.504	.674	.100
34.0	1.800	1.530	1.070	.261	-.054	-.028	-.191	-.456	-.539	-.377	-.170	-.039	-.141	-.142	.515	.851	.242
33.0	1.830	1.560	1.060	.197	-.105	-.051	-.188	-.426	-.493	-.360	-.155	-.035	-.182	-.225	.489	.987	.372
32.0	1.840	1.560	1.030	.163	-.157	-.082	-.183	-.385	-.435	-.338	-.140	-.021	-.215	-.309	.431	1.080	.472
31.0	1.800	1.540	.988	.152	-.197	-.115	-.179	-.339	-.366	-.310	-.122	-.005	-.242	-.388	.359	1.120	.529
30.0	1.740	1.500	.939	.151	-.219	-.142	-.177	-.289	-.291	-.277	-.103	-.002	-.266	-.455	.288	1.120	.540
29.0	1.640	1.450	.892	.151	-.225	-.160	-.174	-.237	-.216	-.240	-.083	-.022	-.288	-.502	.230	1.090	.505
28.0	1.530	1.390	.849	.145	-.222	-.172	-.162	-.184	-.149	-.201	-.061	-.062	-.307	-.528	.185	1.030	.436
27.0	1.420	1.330	.806	.129	-.217	-.185	-.135	-.130	-.095	-.161	-.039	-.109	-.318	-.535	.147	.959	.344
26.0	1.320	1.270	.758	.106	-.219	-.201	-.097	-.077	-.057	-.122	-.020	-.149	-.321	-.528	.113	.889	.241
25.0	1.240	1.220	.703	.077	-.230	-.220	-.059	-.025	-.031	-.087	-.007	-.168	-.313	-.511	.080	.831	.140
24.0	1.180	1.160	.642	.043	-.245	-.236	-.036	.020	-.013	-.059	-.003	-.164	-.292	-.486	.057	.790	.048
23.0	1.140	1.110	.581	.008	-.255	-.243	-.036	.054	.001	-.041	-.012	-.141	-.261	-.456	.050	.759	-.028
22.0	1.100	1.060	.521	.026	-.252	-.241	-.054	.073	.018	-.032	-.032	-.110	-.219	-.422	.059	.732	-.090
21.0	1.050	1.010	.461	-.058	-.234	-.233	-.080	.082	.041	-.027	-.061	-.086	-.173	-.383	.079	.699	-.140
20.0	.986	.957	.399	-.086	-.202	-.228	-.104	.090	.074	-.020	-.095	-.077	-.128	-.342	.103	.654	-.182
19.0	.898	.910	.337	-.104	-.152	-.228	-.134	.098	.127	-.015	-.140	-.086	-.086	-.297	.131	.594	-.212
18.0	.795	.883	.293	-.097	-.085	-.254	-.210	.098	.266	-.018	-.200	-.124	-.054	-.240	.172	.530	-.219
17.0	.669	.877	.267	-.078	-.043	-.363	-.390	.091	.692	-.013	-.360	-.240	-.060	-.194	.214	.461	-.212
16.0	.535	.827	.252	-.056	-.043	-.501	-.683	.244	1.190	-.008	-.540	-.320	-.016	-.125	.241	.390	-.163
15.0	.407	.708	.242	-.038	-.080	-.611	-1.040	.624	1.580	-.025	-.710	-.410	.118	-.018	.255	.320	-.082
14.0	.299	.550	.235	-.026	-.127	-.669	-1.400	1.150	1.800	-.089	-1.000	-.500	.307	.112	.279	.258	-.001
13.0	.215	.411	.233	-.011	-.166	-.694	-1.700	1.660	1.970	-.202	-1.200	-.600	.460	.237	.332	.211	.054
12.0	.154	.333	.241	.015	-.201	-.726	-1.940	2.020	2.200	-.339	-1.400	-.700	.503	.339	.412	.179	.074
10.0	.072	.265	.247	.091	-.296	-.796	-2.100	2.340	2.520	-.576	-1.870	-.902	.377	.511	.522	.125	.053
8.0	.002	.217	.269	.172	-.374	-.799	-1.850	2.240	2.280	-.690	-1.630	-.820	.202	.633	.541	.073	-.024
6.0	-.077	.193	.279	.189	-.382	-.755	-1.460	1.810	1.860	-.523	-1.310	-.667	-.003	.690	.525	.020	-.087
4.0	-.095	.167	.213	.131	-.279	-.653	-1.180	1.350	1.420	-.196	-1.030	-.521	-.108	.657	.400	.004	-.129
2.0	-.052	.105	.123	.048	-.141	-.414	-.779	.819	.844	.002	-.628	-.294	-.067	.376	.196	.012	-.120
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

T (IN UNITS OF 100. DEGREES KELVIN) FOR JULY

	SOUTH							LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	2.523	2.540	2.567	2.599	2.635	2.665	2.689	2.710	2.717	2.709	2.694	2.706	2.724	2.752	2.792	2.830	2.870
47.5	2.501	2.515	2.536	2.572	2.614	2.646	2.668	2.688	2.695	2.692	2.680	2.690	2.704	2.734	2.769	2.802	2.827
45.0	2.449	2.462	2.483	2.517	2.563	2.603	2.625	2.643	2.648	2.647	2.639	2.648	2.662	2.690	2.724	2.756	2.770
42.5	2.389	2.404	2.424	2.455	2.498	2.538	2.563	2.578	2.583	2.582	2.578	2.583	2.598	2.624	2.658	2.691	2.702
40.0	2.323	2.341	2.367	2.400	2.440	2.477	2.502	2.515	2.520	2.518	2.517	2.521	2.535	2.558	2.591	2.620	2.630
37.5	2.255	2.276	2.308	2.347	2.388	2.423	2.446	2.459	2.464	2.465	2.464	2.468	2.480	2.501	2.529	2.555	2.564
35.0	2.189	2.213	2.250	2.295	2.338	2.373	2.396	2.409	2.413	2.414	2.413	2.417	2.429	2.448	2.473	2.493	2.504
34.0	2.163	2.188	2.227	2.274	2.319	2.354	2.377	2.389	2.393	2.393	2.394	2.397	2.410	2.427	2.452	2.472	2.481
33.0	2.136	2.164	2.204	2.253	2.299	2.335	2.360	2.370	2.373	2.374	2.374	2.378	2.390	2.407	2.431	2.452	2.461
32.0	2.109	2.140	2.183	2.233	2.280	2.317	2.343	2.351	2.354	2.354	2.355	2.359	2.371	2.387	2.411	2.433	2.442
31.0	2.082	2.115	2.162	2.214	2.262	2.300	2.325	2.334	2.335	2.335	2.338	2.341	2.353	2.366	2.391	2.414	2.424
30.0	2.055	2.093	2.142	2.194	2.243	2.283	2.308	2.315	2.317	2.316	2.320	2.324	2.335	2.346	2.371	2.395	2.408
29.0	2.029	2.071	2.123	2.175	2.225	2.265	2.290	2.295	2.297	2.297	2.300	2.306	2.315	2.327	2.352	2.378	2.392
28.0	2.005	2.051	2.105	2.155	2.206	2.248	2.273	2.277	2.278	2.278	2.282	2.289	2.297	2.308	2.334	2.362	2.377
27.0	1.981	2.031	2.088	2.139	2.190	2.233	2.256	2.258	2.259	2.259	2.265	2.271	2.280	2.292	2.318	2.347	2.363
26.0	1.960	2.014	2.074	2.125	2.176	2.218	2.239	2.239	2.239	2.240	2.246	2.253	2.261	2.277	2.304	2.334	2.351
25.0	1.940	1.998	2.061	2.114	2.166	2.204	2.220	2.219	2.219	2.219	2.226	2.235	2.244	2.263	2.291	2.322	2.340
24.0	1.924	1.985	2.051	2.107	2.157	2.189	2.201	2.198	2.197	2.196	2.205	2.216	2.229	2.250	2.280	2.313	2.332
23.0	1.913	1.976	2.044	2.103	2.151	2.175	2.182	2.176	2.173	2.173	2.182	2.197	2.214	2.240	2.271	2.305	2.326
22.0	1.907	1.971	2.042	2.103	2.147	2.163	2.161	2.151	2.147	2.147	2.159	2.177	2.200	2.230	2.264	2.300	2.321
21.0	1.906	1.971	2.044	2.106	2.145	2.152	2.138	2.124	2.119	2.120	2.133	2.157	2.186	2.224	2.261	2.296	2.318
20.0	1.908	1.974	2.052	2.114	2.145	2.137	2.113	2.092	2.086	2.089	2.104	2.133	2.172	2.217	2.260	2.295	2.317
19.0	1.915	1.980	2.062	2.124	2.147	2.123	2.082	2.053	2.044	2.049	2.069	2.104	2.155	2.211	2.260	2.297	2.319
18.0	1.926	1.989	2.072	2.136	2.152	2.109	2.048	2.008	1.995	2.004	2.029	2.073	2.137	2.207	2.264	2.302	2.321
17.0	1.938	1.999	2.080	2.144	2.153	2.097	2.019	1.973	1.959	1.971	1.997	2.047	2.124	2.207	2.272	2.309	2.326
16.0	1.951	2.009	2.086	2.149	2.156	2.097	2.019	1.979	1.969	1.979	1.997	2.044	2.119	2.210	2.278	2.314	2.330
15.0	1.962	2.017	2.092	2.155	2.166	2.114	2.056	2.031	2.027	2.032	2.039	2.071	2.130	2.213	2.281	2.316	2.332
14.0	1.971	2.023	2.095	2.158	2.174	2.141	2.115	2.107	2.108	2.109	2.110	2.122	2.154	2.214	2.275	2.311	2.329
13.0	1.977	2.027	2.095	2.156	2.180	2.173	2.180	2.186	2.189	2.190	2.189	2.187	2.190	2.218	2.263	2.297	2.322
12.0	1.981	2.032	2.096	2.153	2.189	2.211	2.243	2.259	2.266	2.267	2.264	2.253	2.238	2.235	2.253	2.277	2.303
10.0	2.017	2.074	2.135	2.199	2.261	2.319	2.372	2.398	2.409	2.410	2.403	2.390	2.364	2.326	2.290	2.270	2.269
8.0	2.125	2.178	2.239	2.307	2.390	2.450	2.507	2.533	2.546	2.546	2.538	2.525	2.496	2.451	2.401	2.361	2.338
6.0	2.237	2.287	2.353	2.427	2.506	2.580	2.633	2.662	2.673	2.673	2.663	2.650	2.617	2.570	2.528	2.488	2.453
4.0	2.347	2.394	2.462	2.545	2.632	2.703	2.751	2.778	2.790	2.789	2.780	2.767	2.733	2.685	2.643	2.600	2.561
2.0	2.445	2.495	2.570	2.657	2.739	2.806	2.854	2.879	2.890	2.889	2.881	2.868	2.836	2.789	2.744	2.703	2.668
0.0	2.530	2.590	2.670	2.753	2.825	2.889	2.943	2.966	2.977	2.976	2.971	2.960	2.928	2.883	2.838	2.793	2.744

KZZ (IN UNITS OF .00001 KMSQ/SEC) FOR JULY

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	10	20	30	40	NORTH 50	60	70	80
50.0	2.775	2.640	3.247	6.663	5.953	1.174	.247	.224	.253	.229	.244	.284	.540	1.761	1.533	1.363	2.353
47.5	2.375	2.259	2.779	5.702	5.094	1.005	.211	.191	.217	.196	.209	.243	.462	1.507	1.312	1.166	2.014
45.0	1.975	1.878	2.311	4.741	4.236	.835	.176	.159	.180	.163	.174	.202	.384	1.253	1.091	.969	1.675
42.5	1.575	1.498	1.842	3.780	3.377	.666	.140	.127	.144	.130	.139	.161	.306	.999	.870	.773	1.335
40.0	1.174	1.117	1.374	2.819	2.519	.497	.104	.095	.107	.097	.103	.120	.229	.745	.649	.576	.996
37.5	1.001	.952	1.171	2.403	2.147	.423	.089	.081	.091	.082	.088	.102	.195	.635	.553	.491	.849
35.0	.827	.787	.968	1.987	1.775	.350	.074	.067	.075	.068	.073	.085	.161	.525	.457	.406	.702
34.0	.758	.721	.837	1.820	1.626	.321	.067	.061	.069	.062	.067	.078	.147	.481	.419	.372	.643
33.0	.689	.655	.806	1.653	1.477	.291	.061	.055	.063	.057	.061	.070	.134	.437	.380	.338	.584
32.0	.619	.589	.725	1.487	1.328	.262	.055	.050	.056	.051	.054	.063	.120	.393	.342	.304	.525
31.0	.550	.523	.643	1.320	1.179	.233	.049	.044	.050	.045	.048	.056	.107	.349	.304	.270	.466
30.0	.480	.457	.562	1.154	1.031	.203	.043	.039	.044	.040	.042	.049	.093	.305	.265	.236	.407
29.0	.440	.418	.514	1.056	.943	.186	.039	.035	.040	.036	.039	.045	.086	.279	.243	.216	.373
28.0	.399	.379	.467	.958	.856	.169	.035	.032	.036	.033	.035	.041	.078	.253	.220	.196	.338
27.0	.358	.341	.419	.860	.768	.151	.032	.029	.033	.030	.032	.037	.070	.227	.198	.176	.304
26.0	.317	.302	.371	.762	.681	.134	.028	.026	.029	.026	.028	.032	.062	.201	.175	.156	.269
25.0	.277	.263	.324	.664	.593	.117	.025	.022	.025	.023	.024	.028	.054	.175	.153	.136	.234
24.0	.236	.224	.276	.566	.506	.100	.021	.019	.021	.019	.021	.024	.046	.150	.130	.116	.200
23.0	.195	.185	.228	.468	.418	.082	.017	.016	.018	.016	.017	.020	.038	.124	.108	.096	.165
22.0	.154	.147	.180	.370	.331	.065	.014	.012	.014	.013	.014	.016	.030	.098	.085	.076	.131
21.0	.113	.108	.133	.272	.243	.048	.010	.009	.010	.009	.010	.012	.022	.072	.063	.056	.096
20.0	.073	.069	.085	.174	.155	.031	.006	.006	.007	.006	.006	.007	.014	.046	.040	.036	.062
19.0	.089	.089	.089	.166	.161	.076	.019	.008	.012	.012	.016	.019	.045	.056	.042	.042	.042
18.0	.093	.093	.093	.159	.167	.120	.032	.010	.018	.017	.026	.031	.076	.066	.044	.044	.044
17.0	.097	.097	.097	.151	.173	.165	.044	.012	.023	.023	.036	.043	.107	.076	.046	.046	.046
16.0	.101	.101	.101	.143	.174	.196	.056	.016	.029	.028	.045	.056	.138	.086	.048	.048	.048
15.0	.102	.102	.102	.139	.156	.171	.061	.026	.057	.027	.043	.055	.136	.113	.064	.064	.064
14.0	.103	.103	.103	.136	.139	.146	.066	.036	.086	.026	.041	.054	.134	.140	.080	.080	.080
13.0	.104	.104	.104	.132	.122	.121	.071	.046	.114	.025	.039	.053	.133	.167	.096	.096	.096
12.0	.107	.107	.107	.128	.105	.096	.090	.060	.140	.034	.052	.069	.131	.195	.140	.059	.055
10.0	.090	.090	.090	.125	.392	.151	.143	.102	.208	.064	.091	.115	.198	.177	.135	.072	.076
8.0	.097	.097	.095	.282	.709	.239	.229	.175	.311	.120	.160	.192	.297	.221	.155	.070	.102
6.0	.176	.186	.193	.424	.854	.379	.366	.300	.463	.226	.281	.321	.444	.357	.284	.110	.140
4.0	.363	.373	.381	.641	1.030	.599	.585	.512	.687	.425	.491	.536	.666	.576	.496	.263	.303
2.0	.735	.748	.756	.977	1.243	.948	.937	.877	1.017	.798	.858	.897	.999	.929	.865	.627	.665
0.0	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500

KFZ (IN UNITS OF .001 KMSQ/SEC)   FOR   JULY

				SOUTH				LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	.540	1.227	1.635	1.642	2.237	.547	-.011	-.004	-.022	-.030	-.024	-.038	-.030	-.177	-.177	-.133	-.059
47.5	.635	1.444	1.925	1.932	2.237	.547	-.012	-.003	-.022	-.029	-.023	-.038	-.030	-.177	-.177	-.133	-.059
45.0	.731	1.660	2.214	2.222	2.495	.581	-.012	-.002	-.022	-.029	-.022	-.039	-.030	-.188	-.188	-.141	-.062
42.5	.750	1.705	2.274	2.283	2.472	.511	-.009	-.002	-.021	-.028	-.021	-.039	-.026	-.186	-.186	-.140	-.062
40.0	.770	1.750	2.334	2.343	2.450	.440	-.007	-.002	-.019	-.026	-.020	-.038	-.021	-.185	-.185	-.139	-.061
37.5	.758	1.722	2.297	2.306	2.519	.346	-.005	-.002	-.017	-.027	-.020	-.042	-.009	-.179	-.179	-.134	-.059
35.0	.746	1.695	2.259	2.269	2.588	.253	-.004	-.002	-.014	-.027	-.020	-.046	.003	-.173	-.173	-.130	-.057
34.0	.755	1.715	2.287	2.297	2.488	.244	-.003	-.001	-.014	-.027	-.020	-.045	-.004	-.175	-.175	-.131	-.058
33.0	.764	1.736	2.315	2.325	2.390	.236	-.003	-.001	-.014	-.028	-.020	-.044	-.010	-.176	-.176	-.132	-.058
32.0	.773	1.757	2.343	2.352	2.291	.227	-.002	-.001	-.014	-.028	-.020	-.043	-.016	-.178	-.178	-.134	-.059
31.0	.782	1.778	2.371	2.380	2.192	.219	-.002	-.001	-.014	-.029	-.020	-.042	-.023	-.180	-.180	-.135	-.059
30.0	.791	1.799	2.398	2.408	2.093	.211	-.001	-.001	-.014	-.029	-.020	-.041	-.029	-.181	-.181	-.136	-.060
29.0	.773	1.758	2.343	2.353	2.010	.224	-.002	-.001	-.016	-.030	-.022	-.044	-.042	-.197	-.197	-.148	-.065
28.0	.755	1.716	2.288	2.298	1.927	.237	-.002	-.002	-.017	-.031	-.023	-.047	-.054	-.213	-.213	-.160	-.070
27.0	.737	1.675	2.233	2.242	1.844	.250	-.003	-.002	-.019	-.032	-.025	-.049	-.066	-.229	-.229	-.172	-.076
26.0	.719	1.634	2.178	2.187	1.761	.263	-.004	-.003	-.020	-.033	-.027	-.052	-.078	-.245	-.245	-.184	-.081
25.0	.701	1.593	2.123	2.132	1.678	.277	-.004	-.003	-.022	-.034	-.028	-.055	-.090	-.261	-.261	-.196	-.086
24.0	.702	1.595	2.126	2.134	1.596	.290	-.005	-.004	-.023	-.035	-.030	-.057	-.103	-.275	-.275	-.206	-.091
23.0	.703	1.597	2.129	2.137	1.513	.303	-.006	-.004	-.025	-.036	-.031	-.060	-.115	-.289	-.289	-.217	-.095
22.0	.703	1.599	2.132	2.139	1.430	.316	-.006	-.004	-.026	-.036	-.033	-.062	-.127	-.303	-.303	-.227	-.100
21.0	.704	1.601	2.134	2.141	1.347	.330	-.007	-.005	-.028	-.037	-.035	-.065	-.139	-.317	-.317	-.238	-.105
20.0	.705	1.603	2.137	2.144	1.264	.343	-.008	-.005	-.029	-.038	-.036	-.068	-.152	-.331	-.331	-.248	-.109
19.0	.701	1.592	2.123	2.131	1.399	.801	.173	.026	-.079	-.095	-.127	-.194	-.387	-.432	-.432	-.324	-.143
18.0	.696	1.582	2.109	2.118	1.533	1.260	.355	.057	-.129	-.151	-.217	-.321	-.623	-.533	-.533	-.400	-.176
17.0	.691	1.571	2.095	2.105	1.667	1.718	.536	.088	-.179	-.207	-.308	-.448	-.858	-.634	-.634	-.476	-.209
16.0	.685	1.556	2.075	2.086	1.759	1.935	.630	.090	-.242	-.244	-.372	-.531	-1.046	-.781	-.781	-.586	-.258
15.0	.796	1.809	2.412	2.424	1.680	1.131	.379	-.023	-.352	-.201	-.330	-.420	-1.045	-1.094	-1.094	-.820	-.361
14.0	.905	2.056	2.742	2.757	1.602	.390	.128	-.094	-.459	-.159	-.289	-.316	-1.045	-1.412	-1.412	-1.059	-.466
13.0	1.013	2.303	3.071	3.088	1.523	-.100	-.093	-.100	-.567	-.112	-.248	-.234	-1.044	-1.736	-1.736	-1.302	-.573
12.0	1.122	2.549	3.399	3.420	1.445	-.100	-.100	-.100	-.672	-.063	-.204	-.212	-1.043	-2.062	-2.062	-1.546	-.680
10.0	-.100	-.100	-.032	-.100	-.100	-.100	-.100	-.100	-.185	.094	.100	.100	.100	.099	-.187	-.186	.054
8.0	-.100	-.095	-.100	-.100	-.100	-.100	-.100	-.100	-.014	.024	.100	.100	.100	.100	.100	-.042	.100
6.0	-.100	-.094	.140	-.100	-.100	-.100	-.098	-.100	-.139	-.188	.081	.100	.100	.100	-.164	-.517	-.150
4.0	.130	.161	1.819	1.494	-.100	-.100	-.100	.008	.016	-.012	.098	.100	.067	-.191	-.674	-.920	-.480
2.0	.390	.756	2.660	3.238	1.554	.387	-.070	-.040	.011	.029	.098	.028	-.419	-.641	-.983	-1.176	-.682
0.0	.296	.565	1.962	2.869	1.710	1.042	.215	-.072	-.035	-.130	.070	-.230	-.382	-.486	-.767	-.921	-.552

KFF (IN UNITS OF KMSQ/SEC)   FOR   JULY

	SOUTH						LATITUDE (DEGREES)						NORTH			
ALT(KM)	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80
50.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47.5	7.324	7.574	7.292	6.157	5.070	2.541	1.778	1.038	.529	.418	.383	.560	.353	.314	.329	.442	.434
45.0	6.683	7.420	7.021	5.831	4.630	2.194	1.475	.861	.426	.323	.281	.468	.308	.258	.242	.364	.395
42.5	6.013	6.454	6.255	5.232	4.019	1.723	1.064	.689	.348	.273	.249	.386	.259	.215	.198	.362	.375
40.0	5.343	5.488	5.488	4.631	3.408	1.251	.653	.517	.270	.224	.218	.304	.209	.172	.155	.361	.354
37.5	4.549	4.582	4.667	4.127	3.142	.910	.474	.363	.212	.202	.198	.271	.171	.143	.143	.312	.310
35.0	3.755	3.675	3.846	3.623	2.876	.569	.296	.210	.154	.181	.178	.240	.133	.114	.132	.263	.266
34.0	3.452	3.388	3.650	3.541	2.689	.532	.263	.195	.147	.177	.175	.227	.134	.110	.132	.257	.258
33.0	3.148	3.100	3.454	3.459	2.501	.496	.230	.180	.141	.174	.172	.214	.135	.107	.132	.251	.250
32.0	2.844	2.812	3.257	3.377	2.313	.459	.197	.165	.134	.170	.168	.201	.136	.103	.131	.244	.242
31.0	2.541	2.524	3.060	3.295	2.125	.423	.165	.150	.128	.167	.165	.188	.138	.100	.130	.237	.234
30.0	2.237	2.237	2.864	3.213	1.937	.386	.132	.135	.122	.163	.161	.175	.139	.096	.129	.230	.225
29.0	2.367	2.405	2.886	3.074	1.831	.396	.148	.154	.131	.163	.166	.179	.147	.110	.133	.208	.206
28.0	2.496	2.573	2.909	2.935	1.725	.405	.163	.173	.141	.164	.171	.183	.155	.124	.136	.186	.186
27.0	2.626	2.741	2.932	2.796	1.619	.414	.179	.191	.150	.164	.175	.187	.163	.138	.139	.164	.166
26.0	2.756	2.909	2.954	2.658	1.513	.423	.194	.210	.160	.165	.180	.191	.171	.152	.143	.141	.146
25.0	2.885	3.076	2.977	2.519	1.406	.432	.210	.228	.169	.165	.184	.195	.179	.166	.147	.119	.127
24.0	3.014	3.244	3.000	2.380	1.300	.441	.226	.247	.178	.165	.189	.199	.188	.180	.150	.097	.106
23.0	3.144	3.413	3.023	2.241	1.194	.451	.241	.266	.188	.166	.193	.203	.196	.194	.153	.074	.087
22.0	3.273	3.581	3.046	2.102	1.088	.460	.256	.284	.197	.167	.198	.207	.204	.208	.156	.052	.067
21.0	3.403	3.749	3.069	1.963	.982	.469	.272	.303	.206	.167	.203	.211	.212	.222	.160	.030	.047
20.0	3.532	3.917	3.092	1.824	.875	.478	.288	.321	.216	.167	.207	.215	.220	.236	.163	.007	.027
19.0	3.344	3.715	3.003	1.868	1.056	.767	.505	.457	.244	.210	.269	.325	.344	.321	.208	.055	.046
18.0	3.156	3.514	2.913	1.912	1.237	1.056	.723	.592	.271	.253	.332	.436	.467	.405	.253	.104	.066
17.0	2.967	3.312	2.824	1.955	1.417	1.345	.940	.727	.298	.296	.394	.546	.591	.489	.299	.153	.085
16.0	2.810	3.153	2.798	2.094	1.705	1.740	1.206	.866	.329	.338	.460	.669	.770	.638	.391	.229	.129
15.0	2.776	3.161	3.019	2.614	2.422	2.561	1.664	1.015	.372	.376	.536	.844	1.170	1.048	.671	.417	.275
14.0	2.743	3.170	3.240	3.136	3.138	3.383	2.122	1.165	.416	.414	.613	1.018	1.569	1.457	.951	.605	.421
13.0	2.709	3.178	3.461	3.656	3.855	4.204	2.581	1.315	.459	.452	.689	1.193	1.969	1.867	1.231	.793	.568
12.0	2.675	3.187	3.682	4.177	4.572	5.025	3.039	1.465	.502	.490	.765	1.367	2.368	2.277	1.512	.982	.714
10.0	3.492	4.151	5.060	5.900	5.794	4.695	2.555	1.210	.365	.324	.505	1.040	2.122	2.708	2.396	1.930	1.634
8.0	3.772	4.393	5.189	5.899	5.296	3.515	1.793	.848	.237	.196	.302	.675	1.494	2.252	2.263	1.989	1.714
6.0	2.965	3.410	3.862	4.187	3.494	2.211	1.075	.512	.171	.164	.230	.460	.903	1.373	1.416	1.298	1.115
4.0	1.942	2.216	2.543	2.701	2.183	1.463	.662	.330	.130	.156	.227	.393	.609	.899	.903	.803	.702
2.0	1.241	1.378	1.632	1.724	1.424	.989	.428	.242	.130	.154	.233	.339	.453	.612	.577	.511	.495
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

V (IN UNITS OF .001 KM/SEC)   FOR   JULY

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	10	20	30	40	NORTH 50	60	70	80
50.0	.091	.134	.144	.133	.065	-.032	-.057	-.016	.021	.028	.034	-.057	-.143	-.136	-.132	-.128	-.104
47.5	-.025	-.059	-.089	-.075	-.259	-.496	-.688	-.763	-.748	-.636	-.492	-.314	-.196	-.185	-.187	-.088	.265
45.0	-.072	-.158	-.188	-.208	-.410	-.646	-.820	-.926	-.966	-.948	-.864	-.709	-.548	-.424	-.295	-.120	.221
42.5	-.064	-.097	-.060	-.109	-.385	-.661	-.870	-1.015	-1.117	-1.165	-1.104	-.954	-.736	-.494	-.277	-.066	.253
40.0	-.064	-.039	.074	.011	-.246	-.444	-.609	-.737	-.846	-.926	-.916	-.840	-.681	-.45.	-.230	-.040	.200
37.5	-.090	-.039	.107	.030	-.149	-.220	-.271	-.343	-.430	-.492	-.507	-.507	-.441	-.309	-.157	-.024	.111
35.0	-.115	-.057	.086	-.007	-.099	-.081	-.058	-.091	-.127	-.134	-.145	-.166	-.178	-.186	-.126	-.067	-.056
34.0	-.087	-.033	.089	.007	-.067	-.043	-.004	-.020	-.034	-.016	-.018	-.046	-.085	-.140	-.127	-.096	-.117
33.0	-.050	.005	.101	.045	-.022	-.007	.031	.030	.042	.079	.086	.060	.006	-.075	-.094	-.088	-.136
32.0	-.032	.033	.101	.080	.029	.031	.058	.067	.101	.150	.165	.152	.089	.006	-.025	-.035	-.079
31.0	-.024	.046	.095	.104	.067	.054	.065	.084	.139	.188	.212	.206	.141	.066	.024	-.005	-.059
30.0	-.029	.042	.090	.117	.088	.064	.058	.085	.156	.204	.226	.229	.167	.107	.062	.021	-.045
29.0	-.029	.035	.087	.127	.098	.067	.051	.078	.157	.199	.218	.225	.177	.129	.083	.039	-.026
28.0	-.031	.022	.079	.123	.091	.056	.036	.061	.137	.175	.189	.196	.169	.136	.085	.039	-.020
27.0	-.037	.008	.068	.109	.074	.037	.018	.041	.107	.140	.151	.157	.154	.137	.082	.043	.014
26.0	-.041	.002	.058	.085	.054	.014	-.007	.012	.062	.094	.103	.111	.129	.121	.065	.036	.035
25.0	-.048	.002	.050	.059	.040	-.006	-.037	-.027	.006	.038	.047	.061	.095	.093	.041	.024	.047
24.0	-.052	.012	.049	.043	.034	-.019	-.071	-.072	-.055	-.026	-.018	.003	.047	.050	.010	.007	.041
23.0	-.054	.028	.062	.045	.040	-.022	-.099	-.117	-.111	-.092	-.088	-.066	-.019	-.008	-.025	-.011	.027
22.0	-.056	.048	.088	.069	.055	-.018	-.114	-.148	-.154	-.148	-.153	-.139	-.094	-.071	-.061	-.026	.017
21.0	-.061	.068	.127	.109	.075	-.011	-.116	-.164	-.178	-.183	-.197	-.199	-.164	-.130	-.094	-.046	-.009
20.0	-.073	.085	.170	.162	.102	-.006	-.114	-.169	-.183	-.188	-.208	-.230	-.204	-.163	-.113	-.060	-.035
19.0	-.095	.102	.203	.181	.098	-.005	-.107	-.165	-.167	-.149	-.176	-.226	-.209	-.158	-.102	-.051	-.032
18.0	-.147	.102	.275	.256	.154	.070	-.087	-.220	-.176	-.042	-.058	-.185	-.205	-.145	-.077	-.024	-.013
17.0	-.153	.071	.282	.296	.225	.179	-.117	-.451	-.332	-.017	.039	-.092	-.161	-.131	-.067	-.018	-.015
16.0	-.062	.023	.135	.155	.175	.207	-.264	-.900	-.696	-.213	-.012	.015	-.070	-.113	-.054	-.058	-.070
15.0	.056	-.016	-.043	-.067	.036	.143	-.511	-1.472	-1.190	-.563	-.174	.072	.007	-.103	-.115	-.120	-.155
14.0	.119	-.026	-.173	-.207	-.083	.034	-.755	-1.943	-1.602	-.855	-.300	.097	.055	-.055	-.073	-.066	-.036
13.0	.090	-.012	-.131	-.172	-.095	-.054	-.870	-2.104	-1.741	-.939	-.315	.054	.040	-.030	-.015	.003	.115
12.0	.022	.000	-.019	-.017	.007	-.097	-.808	-1.899	-1.581	-.830	-.252	.014	-.007	-.040	-.001	.053	.145
10.0	-.054	-.011	.066	.138	.127	-.136	-.514	-1.134	-.955	-.481	-.136	.002	-.009	-.050	-.003	.053	.108
8.0	-.058	-.024	.033	.089	.036	-.117	-.267	-.532	-.400	-.179	-.060	-.001	-.032	-.040	-.026	.005	-.011
6.0	-.021	-.016	.006	.010	.024	-.053	-.063	-.076	.026	.060	.028	.039	-.010	-.030	-.016	-.005	-.039
4.0	.020	-.004	-.017	-.040	-.031	.010	.183	.503	.440	.246	.090	.012	.019	.017	.005	-.009	-.037
2.0	.034	.008	-.040	-.066	-.079	.082	.481	1.099	.859	.404	.132	.011	.045	.030	.041	-.002	-.017
0.0	.008	.003	-.056	-.087	-.066	.082	.369	.573	.236	-.206	-.247	-.036	.134	.206	.103	.004	-.052

W (IN UNITS OF .000001 KM/SEC)   FOR   JULY

ALT(KM)	SOUTH 80	70	60	50	40	30	20	LATITUDE (DEGREES) 10	0	10	20	30	40	NORTH 50	60	70	80
50.0	-9.860	-9.480	-7.840	-6.100	-4.910	-3.390	-1.870	-.640	.426	1.380	2.690	3.170	3.230	3.160	2.930	3.580	5.550
47.5	-6.935	-6.615	-5.595	-4.505	-4.190	-3.075	-1.780	-.507	.456	1.410	2.405	2.685	2.460	2.165	2.055	2.880	4.680
45.0	-5.130	-4.980	-4.160	-3.390	-3.500	-2.700	-1.600	-.459	.413	1.200	1.930	2.220	1.940	1.690	1.770	2.590	4.200
42.5	-3.810	-3.695	-3.100	-2.770	-3.190	-2.530	-1.535	-.572	.204	.923	1.675	2.040	1.890	1.675	1.745	2.375	3.620
40.0	-2.710	-2.490	-2.070	-2.260	-2.990	-2.400	-1.550	-.697	-.042	.649	1.440	1.880	1.950	1.840	1.770	2.160	2.980
37.5	-1.960	-1.540	-1.210	-1.820	-2.530	-1.950	-1.360	-.686	-.212	.363	1.090	1.510	1.785	1.805	1.680	1.850	2.360
35.0	-1.480	-.892	-.638	-1.500	-1.960	-1.360	-1.000	-.598	-.265	.200	.763	1.060	1.410	1.500	1.480	1.480	1.820
34.0	-1.320	-.684	-.475	-1.380	-1.730	-1.130	-.856	-.549	-.240	.180	.642	.892	1.210	1.300	1.360	1.350	1.630
33.0	-1.160	-.511	-.338	-1.250	-1.510	-.929	-.712	-.489	-.193	.177	.535	.734	1.000	1.080	1.230	1.210	1.460
32.0	-.994	-.358	-.226	-1.100	-1.310	-.766	-.583	-.417	-.133	.181	.448	.592	.791	.874	1.080	1.060	1.280
31.0	-.836	-.223	-.134	-.932	-1.130	-.640	-.476	-.338	-.067	.185	.381	.470	.596	.689	.912	.902	1.090
30.0	-.694	-.108	-.056	-.764	-.976	-.544	-.393	-.253	-.000	.182	.328	.369	.424	.533	.747	.740	.899
29.0	-.576	-.013	.016	-.604	-.844	-.472	-.330	-.171	.064	.172	.284	.289	.284	.404	.587	.587	.705
28.0	-.486	.060	.083	-.463	-.736	-.416	-.281	-.099	.120	.158	.245	.226	.181	.296	.438	.452	.523
27.0	-.420	.110	.141	-.349	-.651	-.369	-.240	-.041	.161	.142	.211	.179	.118	.208	.304	.342	.361
26.0	-.373	.143	.182	-.265	-.580	-.334	-.205	.001	.185	.130	.180	.149	.088	.134	.188	.262	.231
25.0	-.340	.166	.204	-.208	-.516	-.314	-.180	.027	.192	.126	.153	.135	.082	.074	.096	.211	.135
24.0	-.313	.189	.206	-.172	-.453	-.312	-.171	.040	.186	.129	.132	.137	.090	.028	.033	.184	.073
23.0	-.286	.219	.198	-.149	-.394	-.327	-.185	.041	.170	.131	.117	.150	.106	.004	.004	.179	.039
22.0	-.254	.264	.192	-.130	-.345	-.353	-.219	.031	.146	.125	.105	.165	.133	.007	.013	.191	.026
21.0	-.219	.328	.203	-.110	-.315	-.384	-.261	.009	.118	.107	.091	.172	.167	.039	.055	.218	.029
20.0	-.183	.413	.237	-.092	-.306	-.414	-.300	-.020	.090	.085	.072	.166	.203	.092	.116	.251	.041
19.0	-.156	.520	.296	-.063	-.323	-.454	-.329	-.047	.073	.069	.046	.147	.238	.147	.177	.280	.053
18.0	-.142	.643	.336	-.075	-.340	-.456	-.355	-.066	.084	.074	-.003	.104	.277	.202	.222	.290	.049
17.0	-.184	.822	.483	-.045	-.346	-.467	-.495	-.139	.218	.198	-.107	-.033	.296	.268	.266	.288	.008
16.0	-.210	.883	.583	.009	-.286	-.484	-.823	-.351	.516	.428	-.128	-.118	.230	.289	.295	.282	.006
15.0	-.179	.754	.539	.056	-.164	-.521	-1.380	-.752	.986	.752	.034	-.061	.074	.249	.304	.280	.077
14.0	-.096	.493	.358	.067	-.027	-.597	-2.130	-1.300	1.580	1.150	.381	.122	-.111	.173	.296	.281	.193
13.0	-.011	.251	.162	.052	.056	-.729	-2.920	-1.880	2.220	1.600	.804	.313	-.246	.115	.285	.278	.286
12.0	.028	.146	.071	.032	.058	-.913	-3.570	-2.380	2.790	2.020	1.160	.397	-.299	.108	.286	.268	.307
10.0	-.021	.206	.218	.139	-.094	-1.410	-4.040	-2.950	3.380	2.560	1.510	.370	-.323	.140	.319	.248	.232
8.0	-.121	.260	.327	.218	-.230	-1.670	-3.660	-2.890	3.300	2.520	1.490	.369	-.352	.139	.356	.225	.157
6.0	-.181	.251	.339	.215	-.252	-1.620	-3.080	-2.510	3.050	2.140	1.230	.308	-.354	.125	.368	.186	.084
4.0	-.145	.180	.262	.142	-.174	-1.340	-2.330	-1.890	2.530	1.590	.881	.203	-.289	.076	.318	.137	.054
2.0	-.070	.082	.157	.063	-.090	-.780	-1.280	-.938	1.380	.874	.445	.100	-.168	.021	.205	.079	.053
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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